ABSTRACT

Title of Dissertation:	LEVERAGING SOCIAL NETWORKS TO FIGHT HIV: THE BATTLE OF FEMALE SEX WORKERS
	Yuruo Li, Doctor of Philosophy, 2020
Dissertation directed by:	Professor Hongjie Liu Department of Epidemiology and Biostatistics

This dissertation aims to assess the applicability of the social network method on HIV research among female sex workers (FSWs).

Manuscript 1 reported the findings from a systematic literature review which examined the application of social network method in HIV studies focusing on FSWs. The majority of the identified studies were limited to local social networks or FSW establishments and did not use sophisticated statistical approaches to analyze sociocentric network data. The discrepancies in network definitions and data collections made it difficult in interpreting their findings and assessing validity. Most of the analytic plans for egocentric studies were limited to information at the individual level rather than that at the ego-alter ties.

The project reported in manuscripts 2 and 3 used empirical data from a multi-center egocentric network study among mid-age FSWs in China to assess the extent to

which social network components influence HIV testing behaviors (paper 2), and the associations between Chinese collectivist culture and FSWs' social networks (paper 3).

As reported in the manuscript 2, among 1,245 FSWs, 62.2% of them received an HIV test. HIV testing was positively associated with higher network transitivity (AOR: 1.77; 95% CI: 1.18-2.64) and inversely associated with network trust (AOR: 0.74; 95% CI: 0.56-0.97). Although social support was not associated with HIV testing, the increase in social cohesion may provide substantial support for HIV testing.

As documented in manuscript 3, Chinese collectivism tendency was negatively associated with their perceived social support (95% CI: -0.33, -0.04), network effective size (95% CI: -0.30, -0.01), and network betweenness (95% CI: -0.33, -0.09). FSWs who had the highest level of collectivistic tendency and perceived a higher level of stigma are more likely to stay at a "bridging" position and connect with weak social ties rather than a strong cohesive group.

This dissertation projects provide empirical evidence that social networks can be used to analyze the social environment of FSWs and its impact on HIV preventive behaviors among this HIV vulnerable population. The findings make additional contributions to the application of social network methods in social and behavioral research with a focus on FSWs.

LEVERAGING SOCIAL NETWORKS TO FIGHT HIV: THE BATTLE OF FEMALE SEX WORKERS

by

Yuruo Li

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2020

Advisory Committee:
Professor Hongjie Liu, Chair
Professor Kenneth Beck, Dean's Representative
Associate Professor Tracy Sweet
Assistant Professor Natalie Slopen
Assistant Professor Quynh Nguyen

Acknowledgements

Thanks to Dr. Hongjie Liu for his guidance and mentorship throughout my doctorate journey. Thanks to all my committee members for the valuable suggestions and support during the manuscript completion. I also want to thank my undergraduate professor in Mathematics, Dr. Rachel Bayless for introducing the idea of social networks to me, even though I received a B in my linear algebra class.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background and Rationale

Despite the global public health efforts to curb the human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) epidemic, up until 2018, an estimated of 37.9 million (32.1 million–44.0 million) people are living with HIV globally (1). Unlike the propagation of most of the infectious disease agents, HIV does not transmit randomly through casual contacts. It is embedded in complex social and sexual relationships. Preventive measurements, such as condom use, requires the agreement of at least two parties for compliance. These special characteristics of HIV transmission make the social network method a natural fit for research aiming to stop HIV/AIDS on a population level.

"A social network consists of a set of nodes (sometimes referred to as actors or vertices in graph theory) connected via some type of relations, which are also called ties, links, arcs or edges" (2). In HIV/AIDS research, the network nodes usually are the high-risk population of interests, such as female sex workers (FSW), men who have sex with men (MSM), intravenous drug users (IDU), etc. Depending on the nature of social relations, network relationships (edges) could be general social contacts, social supports, friendships, sexual contacts, or needle-sharing relationships. For sexually transmitted infections, the risk of each individual to acquire infection not only depends on an individual's behavior but also on the social network they belong to. A sample sexual network is demonstrated in **Figure 1-1.** The red nodes are female sex workers, and the black nodes are their clients. The grey lines between each node indicate sexual relationships. In this network, although wife 1 only has sexual intercourse with her

husband, she is still at high risk for HIV acquisition because her husband is connected with a larger transmission network. Milgram described the phenomenon that every two individuals are connected through a relatively short chain of social relationships as the "small-world theory" (3). Therefore, HIV intervention efforts should not only focus on individual behaviors but also stop the transmission at a network level.

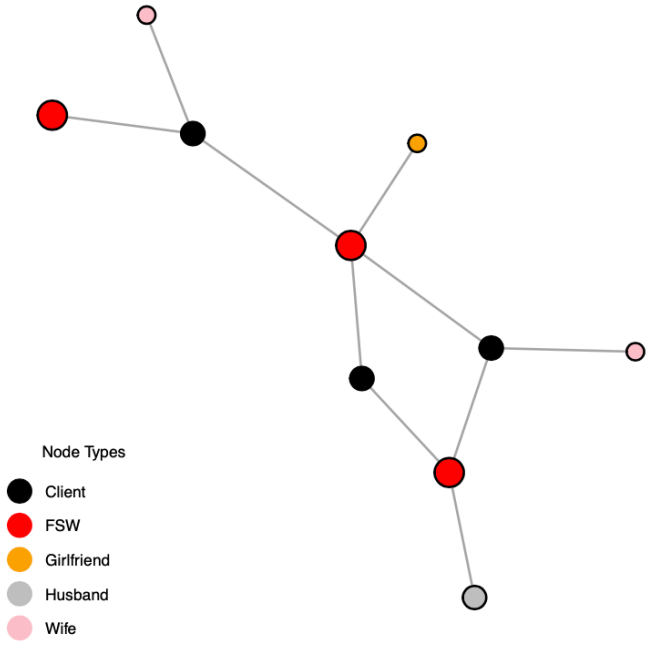


Figure 1-1: A Sample Demonstration of a Sexual Network

Besides transmission networks, social influence and social support networks are also crucial in HIV prevention. Behavioral interventions, such as consistent condom use and needle exchange programs, could significantly reduce an individual's risk of HIV infection. In 1987, before the discovery of antiretroviral drugs, researchers found a significant decline of seroconversions among MSM in San Francisco, solely because of the change in sexual behaviors, such as reducing the frequency of needle-sharing (4,5). However, behavioral interventions targeting the individual behavioral change could only achieve a 25%-40% reduction of HIV risk behaviors (6). Individual's behaviors are not

only determined by their own will, but also determined by their social environment, such as social support, social influence, perceived social norms, etc. (7). Empirical studies found an individual's social networks and environmental factors significantly impact HIV risk behaviors among high-risk populations (8–10). Therefore, studying social networks could provide us important insights for HIV transmission mechanisms and behavioral intervention.

Although social network studies have gained increasing attention in HIV/AIDS research, only a few studies use social network methods and focus on sex workers, especially compared to other high-risk populations such as MSM and IDUs. For example, a systematic review published in 2018 reviewed the association between social networks and HIV risk behaviors among female sex workers. Out of the nineteen studies they reviewed, only three papers, all from one longitudinal study, systematically collected social network data and quantitatively analyzed the network data. This number is exceptionally low compared to MSM and IDU literature (11–15).

To fill the gaps in the literature, the goal of this dissertation is to (1) summarize and analyze the current application of social network methodologies in HIV/AIDS research focusing on female sex workers; (2) explore the association between social networks and HIV preventive behaviors using a egocentric social network sample collected in mid-age female sex workers in China; (3) use the same sample to explore the association between the socio-cultural factors and social networks.

1.1.1 Literature Review (For paper 1)

Qiao et al. (2014) conducted a systematic review on the relationship between social support and HIV-related risk behaviors among high-risk populations including drug users, MSM, transgender women, female sex workers, and HIV positive individuals. Qiao et al. (2014) reviewed the measurements used for social support, including the functions and the structures of social networks, the association between social support and HIV risk behaviors, and how to interpret the results across different populations. This review found that higher social support was generally associated with lower HIV-related risk behaviors among FSWs, people living with HIV/AIDS (PLWHA), and heterosexual adults. However, the association was inconsistent among drug users, MSM, and adolescents (16). Qiao et al. (2014) attributed the inconsistent findings to (1) the effect of social support on HIV risk behaviors might be network dependent. Social supports from drug-using networks would not promote positive behavior change; (2) different social support and HIV risk behaviors measurements may also result inconsistent findings. Social support scales varied a lot in terms of dimensions and items. These inconsistency in measurements scales made studies difficult to be compared with each other (17).

Perkins et al. (2015) reviewed the sociocentric social network studies in low and middle countries with health-related outcomes. They identified the challenges in sociocentric network data collections, including the difficulties in identifying study unit (e.g., an individual, a community or an organization), defining study boundary (e.g., small towns, islands, classroom), and dealing with missing values, and the lack of sufficient analytical methods in these studies. The review suggested that there should be new methods to ensure the accuracy in identifying social ties (18).

Shushtari et al. (2018) reviewed 19 existing studies on the impact of social networks on HIV risk behaviors among female sex workers. This is the only systematic review focusing on female sex workers. They examined the various study designs, the influence of the functional network, the use of network structure, and the main findings of these studies. The author found that majority of the social network studies did not use a name generator, or a social network inventory. A name generator/network inventory is a survey tool that uses a series of questions to generate a list of network members' names and their relationships in data collection. Because of the limited applications of name generators in these studies, social network structures were not investigated in majority of the studies (19). Other systematic reviews focused on the development and the effectiveness of network-level intervention strategies, such as peer education and using social networks to identify key opinion leaders in reducing HIV related risk behaviors (20,21).

However, no systematic review has ever examined the data collection, statistical methods, and interpretation of social network studies in the field of HIV/AIDS among female sex workers. Therefore, **Chapter 3** of this dissertation intended to review and critique the different data collection strategies, social network definitions, and statistical analysis methods being used in social network studies that focus on FSWs and HIV infections. We intend to synthesize the current application of social network methodology on HIV studies among FSWs to identify what has been done and what should be done in the future.

1.2 Background and Rationale (For paper 2-3)

HIV/STI Risk among Female Sex Workers in China

Despite global efforts in HIV prevention, new infections of HIV in China continue to thrive. In 2018, China reported having over one million people living with HIV, with approximately eighty thousand new infections occurring every year. Among these new infections, 69.6% were infected through heterosexual transmission (22). In 2017, 59.3% of heterosexual male cases were contracted through commercial sex exchange (23).

Commercial Sex Industry in China

The commercial sex industry has flourished in China since the 1980s. After the Chinese economic reform and the loosing of government controls, an estimated 10 million women in China were engaged in commercial sex work (24). Although the Chinese government has enforced strict rules against prostitution, demands for commercial sex are still likely to expand as the increasing number of unmarried men. China's one-child policy and its long-standing son preference culture have led to a skewed sex ratio at birth. According to China Statistical Yearbook in 2018, the male to female sex ratio for the population under the 4-year-old was 114.52:100 (25), leaving an estimated 70 million surplus men without a wife by the year 2050 (26,27). Men who are considered "less desirable" in the marriage market are characterized as poor, less educated, and living in rural areas or are the rural to urban migrant workers ("农民工"). Given the difficulties these surplus men face in finding a bride, demands for low-paid female sex workers (FSW) are expected to grow, further exacerbating the HIV epidemic (28–30).

Among all types of female sex workers in China, mid-age female sex workers (aged 35 and above) carry the heaviest burden of sexually transmitted diseases (31,32). Historically, Chinese female sex workers have been classified into three "tiers" based on their charges per service, and mid-age female sex workers are often classified into the lower tier (33,34). High and middle-paid sex workers are predominantly younger, more educated, and more likely to be organized into venues that provide regular clientele and protections (35). Mid-age FSWs, on the other hand, have lower education levels, are more likely to solicit by themselves or in a weakly structured venue (on the street, small beauty parlor, or factories), and therefore charge less for their services. High and middle paying female sex workers tend to enter the sex industry at a younger age and quit sex work in their 30s when they are considered "less competitive" at which point they get married or run a small business. In contrast, mid-age female sex workers are more likely to enter the sex industry when they are 30s because of economic hardship. This hardship often puts them in a more vulnerable position to negotiate condom use or other preventive methods (34,36). Among the three tiers of female sex workers, low-paid FSWs are three times more likely to have HIV infection (31) and four times more likely to have other sexually transmitted infections (STI) (32), compared to high-tier FSWs.

The primary clientele of mid-age female sex workers is rural to urban migrants and low-paid manual workers. The estimated HIV prevalence in these populations is ten times greater than HIV prevalence in the general adult population. These male clients are 3-44 times more likely to have other bacterial STIs such as syphilis, gonorrhea, and chlamydia (37). These low-paid migrant workers are characterized by their high mobility, separation from their long-term partners, higher rates of concurrent partners, and frequent

visits to commercial sex workers (38,39). These workers' high-risk behaviors and the ability to link geographically separated epidemics (from high prevalent to low prevalent regions) would sustain the HIV epidemic among general populations (39,40). Therefore, studying low-paid mid-age female sex workers plays a crucial role in curbing HIV/STI epidemic nationwide.

Social and Political Barriers in HIV/STI prevention

Compared to high-paid FSWs, low-paid mid-age female sex workers are more likely to engage in risky sexual behaviors. Mid-age and low-paid FSWs continued to have low uptake of condom use with their clients (33,34,41). The higher economic pressures, sex work related stigma, and close relationship with clients of are barriers to self-management and preventive behavior change for mid-age FSWs (33). Beyond individual-level factors and self-management, condom use with clients is not determined by FSWs but their clients. The majority of the female sex workers list "clients refused to use a condom" as the main reason for not using condoms in their sex acts (33,36,42).

The political environment in China also increases the vulnerability of female sex workers. Prostitution is illegal in China, and severe penalties are introduced to repeated offenders as a part of anti-HIV efforts (43). Before the1980s, female sex workers were considered "victims" of capitalist patriarchy, and the penalties associated with prostitution were considered as "re-education" rather than punishment. However, since the confirmation of the first HIV cases in China in 1986 and the rising STI epidemics (30), female sex workers have been punished more severely for public health concerns. The state and the Communist party started to further stigmatize FSWs by labeling their reasons for prostitution as materialism and laziness (43). The state enforced periodical

“strike-hard” movement (44,45), a campaign style of policing (Yanda 严打运动) to combat prostitution in China (43). The local law enforcement would periodically ambush entertainment venues to arrest FSWs.

These socioeconomic and emotional vulnerabilities further drive FSWs away from the mainstream discussion and decrease their utilization of preventive healthcare (46). Therefore, identifying the social structural factors that affect Chinese FSWs' preventive behaviors should be prioritized as one of the main intervention strategies to reduce risky sexual behaviors and curb the HIV/STI epidemic among the heterosexual population.

Role of Social Support in HIV/STI Preventive Behaviors

Given the circumstances of mid-age female sex workers in China, the barriers to adopting HIV preventive behaviors are not only determined by their individual factors, but also the social structural factors rooted in the political environment and their social relations. Social network method is the natural fit for studying the immediate social environment of FSWs. The social networks method is rooted in the social capital theory which believe that social relations have values. The word “social capital” refers to the “ability to secure benefits through membership in networks and other social structures” (47). This could be quantified as the function and structural resources embedded in a social network that could determine an individual’s behavior (48).

The functions of network resources are social support, information support, or social influence. Social support has been extensively studied as the facilitators for HIV/STI preventive care (16,49–51). HIV high-risk populations are more likely to access healthcare facilities, use condoms, or participating in needle exchange programs if they

receive more social support from their family and peers (52–54). Positive social norms towards preventive behaviors and information dissemination through social networks are also positively associated with an individual's health overall outcomes (55–57). For example, if a Zambian FSW wants to make friends with other FSWs, she will need to be tested negative for HIV first (58). FSWs in Shandong are more likely to be tested for HIV if testing is important to their family members (59).

In addition to the function of social networks, the structural aspects of social networks are equally important. The shapes and types of social relations have a significant influence on an individual's behavior. Putnam argued that there are two types of relational effects in social networks, bonding and bridging. Networks composed of a group of homogenous social contacts are predominantly bonding networks, such as friends, family, and organizational groups (60). Members of these networks are interconnected and provide repeated social influences to reinforce behavioral changes (61). These dense networks can "provide crucial social and psychological support for less fortunate members of the community" (62).

Although a strong and dense family and friends' network could psychologically empower FSWs to negotiate for condom use with their clients, the effects of network bonding are not always positive. Harmful social norms and deviant behaviors are more likely to be tolerated in close-knit networks, especially among socially marginalized populations (63). Intravenous drug users (IDUs) are more likely to exchange sex for money if they have other IDUs in their networks (64). Migrant workers are also more likely to patronize a prostitute if their networks are composed of interconnected migrant workers (65).

Different from network bonding effects, networks with more bridging potential could help individuals get resources outside of their social circle and for information diffusion. A person is in a bridging position if two individuals could only be connected through that person. Hence, this type of network is less interconnected, contains network members who are less bounded, has fewer common features, and is usually less emotionally connected. These network relations are known as the "weak ties" (66). Because of the differences among them, new information will be more likely to flow within the network, leading to more opportunities for collaboration and innovation (62,67). Similarly, for FSWs, having a social network with more diversified social contacts could help them gain more information and potentially provide them with opportunities outside of sex work.

In addition to the traditional benefits of the "bridging network," this network pattern may give FSWs and other socially marginalized populations more social power to control the information flow within a social network. When two unlinked individuals both connected with a mutual third person, this third person is considered as the "bridge" between the two individuals. And that third person has the social power to decide how much information could flow between the two individuals who are not connected otherwise.

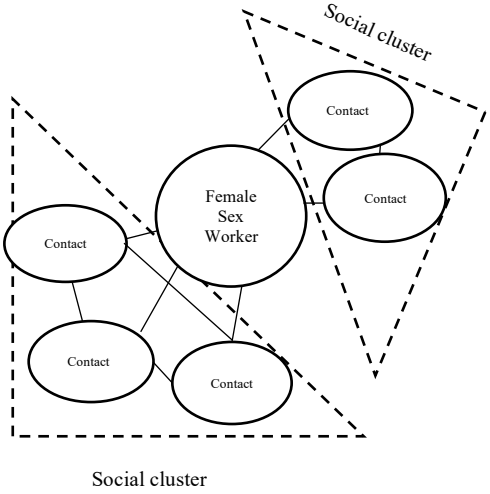


Figure 1-3: A social network with "bridging potential"

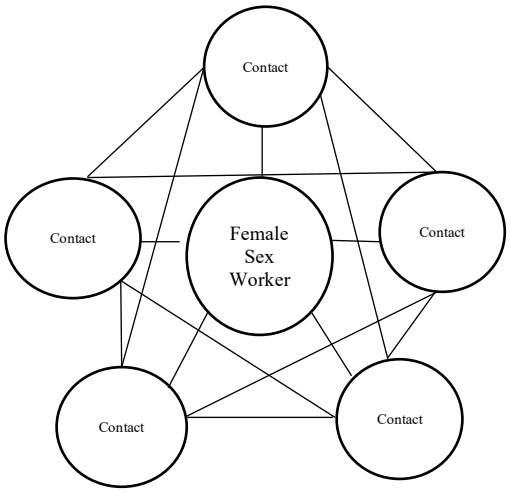


Figure 1-2: A close-knit social network

Being at a "bridging position" gives crucial structural advantages to FSWs to secure their social contacts. Because of the stigma around sex work, most of the FSWs conceal their identity from their family and friends. In a close-knit community, exposing their identity to any social contact put FSWs at risk for losing all of their social contacts (Error! Reference source not found.). On the contrary, in a sparser social network, even if one social contact finds out about the information, they cannot spread it to FSWs' entire social network (**Figure 1-3**). An empirical study had found that FSWs who had more bridging potential in their social networks received more social support from their network members (68). Men who have sex with men (MSM) were more likely to put themselves in a "bridging position" after the positive HIV diagnosis to cope with the potential stigma and discrimination from their networks (13). Unfortunately, limited literature has been focused on the structural effects of FSWs' social networks on HIV preventive behaviors. This study plans to fill the literature gap by investigating the network structural effects on HIV testing behaviors among mid-age FSWs in China and how the Chinese social and cultural contexts influence FSWs' social networks.

1.2.1 Literature Review (Chapter 4)

Recent studies suggest that individual, interpersonal and societal factors contribute to the low HIV testing rate among female sex workers (46,69–71). Tokar et al. (2018) identified that older age, having children, higher perceived risk, social support (from family, peers, and pimps/venue owners), peer education and having access to health professionals are all facilitators for HIV testing behaviors among female sex workers (69). HIV and sex work stigma, negative attitudes towards fellow FSWs, social marginalization, discrimination from healthcare workers cost, and crimination of sex workers are all barriers to HIV testing behaviors for FSWs (69).

Social network characteristics significantly influence HIV preventive behaviors among FSWs (19,72–76). Social networks are the main source of information for female sex workers (63). However, the influence of social networks is not always positive. Higher levels of perceived social support are associated with the uptake of preventive behaviors (72,75,76), but the impact may differ based on the source of social support (53). Higher levels of perceived support from clients or sexual partners are negatively correlated with HIV preventive behaviors (53,77), but support from family and FSW friends has a positive influence on FSWs' HIV preventive behavior (72,75,76).

Several qualitative studies identified that the lack of HIV knowledge and HIV service information (58,78), perceived low risk of HIV (78), fear of positive results (78,79), low trust in healthcare professionals (58,78), lack of social support (78), and fear of stigma (58,78–80) are associated with low HIV testing uptake. Qualitative studies specifically focusing on social networks and HIV testing revealed that the amount of

perceived social support (81,82), social cohesion (83), and social participation (83) are all positively associated with HIV testing behaviors.

We identified five papers that examined the correlation between social support and HIV/STI testing among Chinese FSWs (35,46,59,70,71). Most studies found that support from workplace contacts, including fellow FSWs and gatekeepers, are important facilitators for HIV/STI testing (46,59,70,71). One study found that social support from family and friends is not associated with HIV testing (46), and other studies suggested otherwise (35,59). Three studies quantitatively examined the association between HIV testing and social support (46,59,70). Wang and colleagues used dichotomized measurements for social support, such as asking FSWs whether they are willing to test for HIV if another FSW has been tested (46,59). Hong et al. (2008) utilized an 8-item scale to evaluate whether FSWs' managers provided the necessary tangible and emotional support for FSWs to get HIV tested (70). None of these studies systematically examined the association between social network characteristics and FSWs' HIV testing behaviors using social network methods (i.e., using name generators in data collection). No study has ever examined the association between the structure of social networks and HIV testing behaviors among female sex workers (71,84).

A few studies have investigated the influence of social network structure in HIV testing behavior among the MSM community. In a cross-sectional study among young MSM in Detroit, Veinot et al. (2016) examined how the structures of MSMs' personal networks related to their HIV testing uptake (55). This study found that a higher network range (i.e., how many types of social relations an individual has) was positively associated having at least one HIV test in their lifetime. Higher network homophily (i.e.,

the level of similarities among network members) was positively associated with having an HIV tested within the last 12 months (55). Wagner et al. (2015) found that higher levels of network centralization, a measure of the degree to which one or a few individuals maintain the majority of the ties in the network, was positively associated with having at least one HIV test in their lifetime (85). Network density, another measure of network cohesion, was not associated with HIV testing (85). These two studies demonstrated a possible correlation between network structures and HIV testing behaviors. However, limited researches have ever investigated the correlation between social network structures and HIV testing behaviors among FSWs. Therefore, more research is needed to explore other network measurements to better explain the mechanism behind the effects of social networks on HIV preventive behaviors among female sex workers in China.

1.2.2 Literature Review (Chapter 5)

Although the association between social networks and health outcomes has been well-researched in previous literature (19,86,87), few studies focused on the factors associated with the composition and structure of social networks. McFadden et al. (2014) found that positive HIV results significantly changed the social networks of young black MSM (YBMSM) in Chicago (13). After a positive HIV diagnosis, the percentages of family and relatives in YBMSM's personal network decreased. Their network cohesion and density also decreased but the network betweenness was increased. Network betweenness measures the "bridging" potential of an individual's social network (88). A sparser network with a more "bridging" position increased YBMSM's control of the information flow across their personal networks as the coping mechanism for the positive diagnosis (13). In addition to HIV results, involvement in criminal justice, sexual orientation, economic hardship, and risk behaviors were associated with the change of social networks as well (11,89,90). The aforementioned literature was published from the uConnect, a prospective longitudinal cohort study targeting YBMSM in Chicago. To our knowledge, no other research has investigated the network dynamics of other HIV key populations (e.g., FSWs, intravenous drug users, etc.). To fill this research gap, the present study examines factors associated with the function, composition and shape of FSWs' social networks in China.

Two factors, collectivistic tendency and occupational stigma, might influence the social networks of Chinese FSWs. Chinese culture is predominantly collectivistic. Because of the long history of cultural and socialist political ideology, Chinese people emphasize group values over individual values (91,92). Although collectivist cultures

promote interconnected community and harmony within social groups, the relationship between FSWs and their social contacts may not be very friendly. A recent study found that collectivistic tendency is positively associated with ingroup vigilante. People with higher collectivistic tendency are more likely to have competitive rather than cooperative in-group relationships (93). Similarly, the collectivistic tendency might be a barrier for FSWs to receiving adequate social support and new information from their social networks. For FSWs' social networks, the shame from having a sex worker in their social circle may outweigh the benefits of having an emotional or social bond with her. FSWs believe that their family and friends would be ashamed once their identity as an FSW is revealed (94). Social stigma related to sex work, exacerbated by the collectivistic Chinese culture, might force FSWs to be more selective with their network. Some empirical studies found that FSWs' collectivistic attitude toward family members is positively associated with their perceived self-stigma (fear of societal judgment and negative attitudes) (95). But their collectivistic attitude toward friends and neighbors were negatively associated with their public-stigma (negative attitudes and judgment endorsed by society) and self-stigma (95). Similar to FSWs, the collectivistic tendency is also positively associated with stigma and discrimination against homosexuality among the MSM population in China (96). However, limited research has focused on the interplay among collectivism, social stigma, and social networks for FSWs.

1.3 Objectives/Research Questions

The overarching goal of this dissertation is to explore how to leverage social network methods to increase the uptake of HIV preventive behaviors among female sex workers. The dissertation is organized as follows:

Specific Aim 1 (Paper 1): This proposed study aims to summarize and critique the current applications of social network methods in HIV studies focusing on female sex workers. This study will critically discuss the research question, social network measurements, and analytical plan of all the identified studies.

Specific Aim 2 (Paper 2): This study will use a unique sample of egocentric social network survey collected among mid-age FSWs in China to explore the association between social network characteristics and HIV testing behaviors.

a. What factors may influence the HIV testing behaviors of mid-age FSWs in China?

b. How do social support networks influence the HIV testing behaviors of mid-age FSWs in China?

Specific Aim 3 (Paper 3): This study will use the same data from aim 2 to investigate how the higher-level socio-cultural influence the function and structures of social support networks among mid-age FSWs in China.

a. Does occupational stigma (as a female sex worker) influence the social support networks of mid-age female sex workers in China?

b. Does collectivism tendency toward friends the social support networks of mid-age female sex workers in China?

c. Does occupational stigma modify the relationship between collectivism and social network measurements.

1.4 Theoretical/Conceptual Framework

The conceptualization of this study is based on the social-ecological model and the social network resource model. The social-ecological model integrates individual, interpersonal, and socio-cultural determinants of behaviors to explain the dynamic nature of sexual behavior (97–99). The social-ecological model suggests that individual behaviors are determined not only by an individual's own psychological predisposition, but also by the production of the environmental and policy context of the behavior. There are three main aspects of an individual's social environment: sociocultural factors, such as social stigma, cultural practice, government policy, etc.; interpersonal factors, such as social networks, community influences, caregiver influences, etc.; and individual factors, such as education level, health literacy, beliefs, etc.; (**Figure 1-4**) (6,100).

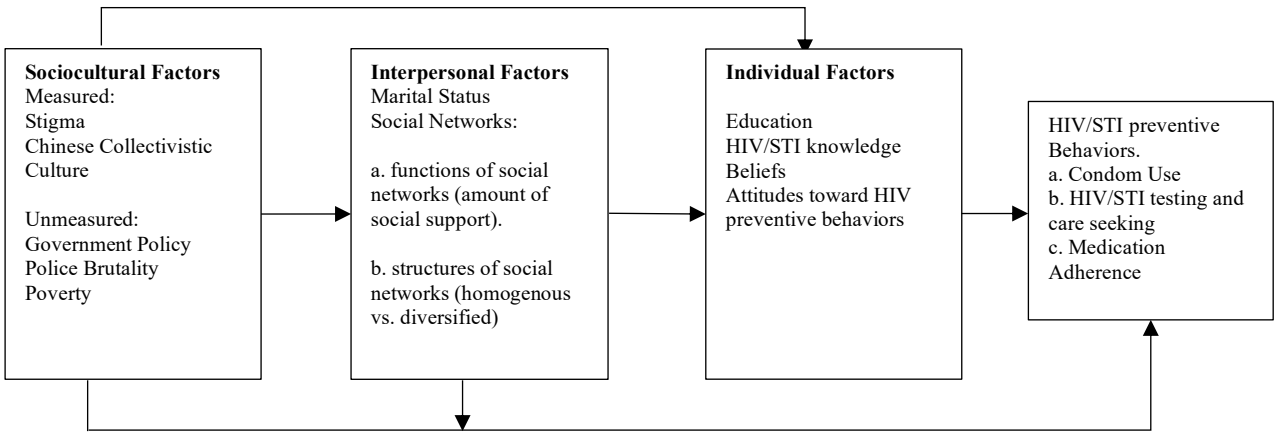


Figure 1-4: Social Ecological Model Conceptual Framework

The present study specifically focuses on the interpersonal level of the social ecology model, social networks. Johnson et al. proposed a network-individual-resources model for HIV prevention to explain the mechanism of how social networks influence an individual's HIV preventive behaviors (97). There are two primary resources embedded

in an individual's social networks: mental/emotional resources such as enabling positive attitudes, social norms, positive social influences, self-efficacy, etc., and tangible resources such as partner's income, shared possessions, or specific items such as condoms. Access to these network resources facilitates HIV preventive behaviors by enabling individuals to survive and thrive using their network resources. For example, people with inadequate resources have less power to cope with stressful life events, and people are more risk-averse when they feel safe. They are also more likely to trade distal, probabilistic HIV concerns for tangible and proximal needs. If a client offers more money for unprotected sex, FSWs with limited resources are more likely to accept the offer than FSWs who have a social support system. In addition to the importance of network resources, network trust plays a central role in HIV prevention. The positive social influence could only be delivered through trusted social contacts but trust towards sexual partners results declining in condom use (97).

In addition to social influence, an individual's social network also shapes the risk of HIV infection and the patterns of HIV transmission in a society. An individual's risk for HIV is not only determined by their behaviors, but also by their connected sexual networks. An individual is at high risk for HIV even if they are only connected to one HIV high-prevalence group. Therefore, network-level intervention should focus on finding the appropriate method to disrupt the connections between HIV negative individuals and HIV high-risk populations. This disruption is more difficult among individuals with limited tangible and mental resources and needs to be administered in a culturally appropriate manner (97). Therefore, combining the social-ecological model

with the network-individual-resource model is appropriate to curb the HIV epidemic among FSWs in China.

1.5 Innovation and Significance

Chapter 3 (Paper 1): An important challenge to the current literature of social network studies on female sex workers and HIV risk is the gap between developing social network methodology and applying it to the real world. Although several social network methods have been developed to analyze social network data, the primary study design and data collection have many difficulties in compliance with the assumptions of these statistical methods (i.e., the research unit in network data are not independently sampled). Therefore, a comprehensive review of current application of social network methodologies in HIV/AIDS research for FSWs is needed to bridge the gap between the social network theories and the application of the methods in preventive research. In addition, although social network studies often face difficulties to generalize the findings from one network to the population, behavioral studies focusing on HIV/AIDS need to be generalizable to design appropriate intervention strategies. This review helps the future researchers to establish consensus on the data collection, study design, and statistical analysis for similar studies.

Chapter 4 (Paper 2): Regular HIV testing is crucial in diagnosing HIV infections at an early stage, especially for HIV high-risk populations. Early deduction of HIV can help HIV positive individuals to take antiretroviral therapy initiation at an early stage and reduce the frequency of high-risk sexual behaviors. Mid-age FSWs in China is considered as HIV key population. Exploring factors associated with HIV testing among Chinese mid-age FSWs is important in curbing the onward HIV epidemic among the heterosexual population in China.

Paper 2 is innovative because it uses two novel methods to measure social network characteristics and address the potential self-report bias. In this study, we use novel social network predictors to assess the social cohesion of FSWs' social support networks. In traditional HIV/AIDS research, social cohesion is measured by a scale of social cohesion and social integration (101,102). A sample question of this scale is, "You can count on your colleagues if you need advice." Although this scale effectively measures the level of social integration of individuals, it does not quantify the number of resources available and the precise relationships within an individual's social network. Therefore, we use a sample collected from an egocentric network that specifically asks the number of social contacts that could provide social resources to the individual. We calculate the level of social cohesion using network structural predictors such as network density, transitivity, effective size, and constraint. It could characterize an individual's social network with greater precision.

Another innovation is that we use a novel method to verify the results to reduce the self-report bias. The primary outcome variable in this study is a self-report HIV testing status. Self-report variables are prone to social desirability bias and recall bias. FSWs may overreport their HIV testing history to avoid moral judgment from the researchers. Similar biases occur in self-report condom use as well. However, different from HIV testing behaviors, which we cannot be verified objectively, recent condom use could be validated through biomarker testing. Prostate-specific antigen (PSA) is a protein that could be found in males' specimens. Female bodies do not have PSA naturally. Females are tested positive for PSA only if they have unprotected sex within 24 hours. Therefore, the self-reported condom use within 24 hours could be verified by the PSA

test (103,104). Since the social desirability biases in both variables are in the same direction, FSWs who overreport their condom use is more likely to report their HIV testing behavior. Thus, we run a subsample analysis to examine the robustness of the association between HIV testing and social network measurements among the FSWs who correctly report their condom use behavior. Since most of the self-report behaviors cannot be validated externally, this test could serve as a potential protocol for sensitivity analysis and reduce the potential social desirability biases in self-report surveys.

Chapter 5 (Paper 3) Although social network characteristics have been linked to individuals' health outcomes, social network-level interventions may not as effective as we hope. A social network is reciprocal. Individuals must commit to helping their network members in order to receive the benefits from them. For example, simply increasing social support to fill the needs based on an individual's health condition may bring greater stress to the patients. Caregivers possessed higher social power over the individual who receive social support from them. This could further increase the perceived stress that an individual faces (105). Therefore, social network intervention should be strategized and culturally appropriate. However, few studies have ever focused on the mechanism and delicacy of individuals' social networks.

This study is innovative because it provides additional insights on how socio-cultural factors may influence social network characteristics among mid-age female sex workers in China. Both sex work related social stigma and Chinese collectivistic culture deeply influenced how FSWs viewed their networks and how they adapt to their social lives. By studying the influence of these two factors on FSWs' social networks, we could design social network intervention in a more effective and culturally appropriate manner.

Chapter 2: Methods

The following chapter contains detailed information about the epidemiologic methods presented in Chapters 3-5.

2.1 Study design and data source (Paper 1)

A systematic literature review was conducted in March 2020 using electronic search in major health science databases, including PubMed, Web of Science, ScienceDirect, EBSCO (Medline) and ProQuest. A total of 6891 articles were identified, and 12 articles were included for the final review. The detailed study design and data collection protocols had been described in Chapter 3.

2.2 Study design and data source (Paper 2-3)

Secondary data analysis was performed for paper 2 and paper 3. This data was derived from a multicenter cross-sectional study based on the research project titled "Social network and sexual risk for HIV/STIs among mid-age female sex workers" supported by NIH grant R01 HD068305-01. This study was carried out in 2014 in Hefei, Nanning, and Qingdao. The three cities were selected based on its level of HIV epidemic. According to China Health Statistical Yearbook in 2019, the HIV incidence in Guangxi (Nanning) is 12.23 per 100,000, Anhui (Hefei) is 2.06 per 100,000 and Shandong (Qingdao) is 0.96 per 100,000 (106). Respondent-Driven Sampling (RDS) was used to recruit FSWs in this study.

Eligibility criteria

The inclusion criteria were participants who (1) were female and lived in either of the three cities for at least three months; (2) were at least 35 years old; and (3) had exchanged sex for money at least once a week in the past month prior to interview.

Sampling Method

Respondent-driven sampling (RDS) is a sampling framework similar to snowball sampling and chain-referral sampling (107,108). It samples study participants based on their social networks. The sampling procedure is described as follows: for each selected city, we worked with the local health departments to identify four or five female sex workers who worked at different durations as sex workers, used different solicitation methods (street worker or venue worker), and met the inclusion criteria. These female sex workers served as the "seeds" for later recruitments. A coupon system was used to track the recruitment process. Each seed was given out three coupons with a unique serial number that allowed them to recruit three different FSWs who met the inclusion criteria. Each seed received 18 yuan (3 US dollars equivalent) as incentive if they successfully recruited an FSW participant (9 USD maximum). Then the researchers repeated this process by distributing three new coupons to the enrolled participants to recruit other qualified participants until the required sample size (400 per city) had been reached. Eventually, there were eight recruitment waves for Qingdao, nine for Hefei and eleven for Nanning. 407-420 participants were recruited at each city and the total sample size was 1245.

Respondent driven sampling is designed to recruit population that cannot be easily recruited through probability sampling. This sampling method has been widely used to recruit marginalized populations such as FSWs, MSMs and IDUs (74,109,110). The respondent-sampling method operates under the assumption of the "small-world" phenomenon, that any pair of randomly selected individuals are linked by relatively few intermediaries (111). In other words, if the enrolled FSWs randomly give out recruitment

coupons to their friends, with a few recruitment waves, we should observe a relatively representative study sample, similar to what we would observe in a random sample (110). Since individual's probability to be included in the study depends on their recruiters and the recruiter's network size, this sample may overrepresent FSWs who have larger social networks. RDS sampling weight adjusted is recommended to reduce this bias (110).

Ethics Consideration

The study protocol was approved by the Institutional Review Board (IRB) of the University of Maryland, Shandong University School of Public Health and local regulatory agencies including Guangxi Center of Disease Control and Prevention, and Hefei Center of Disease Control and Prevention. Written informed consent was obtained for all the participants. The research datasets were deidentified for data analysis and manuscript preparation.

Data collection procedures

Each eligible participant received interviews by trained interviewers using computer-assisted personal interviewing (CAPI) in a private room near the proximity to participants (less than 1 h-travel time). The identities of the study participants were protected, and no information collected in CAPI could be used to identify study participants. For taking part in this research study, FSWs were paid for their time and inconvenience in the amount of up to $18.5 ($9.5 for receiving an interview and $9 for introducing 3 friends to participate in this study).

Egocentric Network Data Collection

This study collected the egocentric support network of FSW participants. The details of the egocentric network data were presented in Chapter 4-5. Egocentric

networks consisted of a focal person, the FSWs (egos) and FSWs' social relationships (alters). In this study, FSWs were asked to list their social contacts who can provide social support to them. Questions regarding each ego' s alters were answered by egos. No "alter" was interviewed in this study.

Chinese Social Network Questionnaire (CSNQ) were used as the social network inventory (86,112). Each ego was asked to provide a list of alters who could provide social support to them based on the following criteria:

1) lend the ego 200 Chinese dollars ($30 US);

2) take care of the ego, if the ego were confined to bed for 2-3 weeks;

3) help or advise the ego if the ego had problems regarding family or health issues;

4) agree with or support the ego's ideas or actions;

5) make the ego feel respected or admired; and

6) convince the ego to confide in the alter.

Alters' first names or pseudonyms were recorded if they met any of the above criteria. Each ego could name up to 30 alters in this study. The observed network size (number of alters each ego named) was 0-21.

*Social Support***:** The above six-item measure for social support covers tangible support (items 1–3) and emotional support (items 4–6). After recording alters' names, researchers would repeat the above questions with a four-point Likert scale: (0) definitely will not provide, (1) probably will not provide, (2) probably will provide, (3) definitely will provide. The level of social support perceived by each ego was the sum score of each social support item. The range of social support from each alter was 0 to 18. The observed total support each ego perceived ranged 2-210. The observed range of tangible

support (sum score of item 1-3) each ego perceived ranged 0-109, and the observed range of emotional support (sum score of item 4-6) each ego perceived ranged 0-104.

Average alter trust: Egos were asked to rate the level of trustiness by answering ""How much do you trust this person?". The answer was on a 5-point Likert scale: (0) Do not trust at all; (1) Do not trust; (2) Do not care; (3) Trust; (4) Very trust. The average alter trust was the average rating of all the alters in ego's network.

Average alter closeness: Egos were asked to rate the level of closeness to each alter by answering "How close are you with this person?". The answer was on a 3-point Likert scale: (0) Not close; (1) Average; (2) Close. The average alter closeness was the average rating of all the alters in ego's network.

*Egocentric Network Measurements***:** The researchers collected each alter's gender, ego-alter relationship (husbands, boyfriends (without commercial sexual exchange), boyfriends (with commercial sexual exchange), FSW friends, non-FSW friends, gatekeepers (managers, senior FSWs, or pimps), regular clients, family members, distant relatives, neighbors or others), age, education status, and marital status. FSWs also identified the relational matrix among the alters by indicating whether two alters knew each other or not. Unfortunately, the level of closeness and the nature of alter-alter relationships were not collected in this data.

Important Variables:

Collectivism: A fifteen-item scale Individualism–Collectivism Interpersonal Assessment Inventory (ICIAI) was used to assess the tendencies of individualism and collectivism (92). ICIAI provides a measure of the tendency toward individualism or collectivism and the perception of individualism and collectivism values with interpersonal orientation in

the friendship relationship. A five-point Likert-scale was used to indicate the level of importance (0 not at all important; 1 somehow important; 2 important; 3 very important; 4 extremely important). The observed range of collectivism was 0-60.

In order to maintain a good friendship with your friends, which of the following items is most important to keep a good relationship?

Table 2-1: 15-Item Scale used to Assess Collectivism towards Friends (113)

1. Maintain self-control toward them
2. Share credit for their accomplishments.
3. Share blame for their failures.
4. Respect and honor their traditions and customs.
5. Be loyal to them
6. Sacrifice your possessions for them
7. Respect them
8. Maintain harmonious relationships with them.
9. Nurture or help them.
10. Maintain harmonious relationships with them. _
11. Maintain a stable environment (e.g., maintain the status quo) with them.
12. Cooperate with them.
13. Communicate verbally with them.
14. "Save face" for them.
15. Follow norms established by them.

Occupational Stigma: Occupational stigma was measured based on an eight-item measurement scale. It was constructed to assess mid-age FSWs' perceptions of stigmatizing attitudes and/or discrimination towards sex workers. Participant responses were ranked on a four-point scale: (0) "strongly disagree", (1) "disagree", (2) "agree", (3) "strongly agree." Scores were summed with a range of 0–24. The observed range of occupational stigma was 6 to 24. This variable was mostly centered at mean. 68% of the participants rated their occupational stigma between 14-17 and 42% of the participants scored at 16. This measurement was validated in our previous publication. The

Cronbach's alpha was 0.86 (114,115). The questions used to ask occupational stigma were:

Do you agree with the following statements about mid-age female sex workers(miss)?

Table 2-2: 8-item Scale to Assess FSWs' Occupational Stigma

1.My none-FSW friends would stop being friends with me if they knew my job.
2. People around me (colleagues or neighbors) would rebel me if they knew my job.
3. My none-FSW friends would look down to me if they knew my job.
4. People around me (colleagues or neighbors) would look down my family me if they knew my job.
5. My family would "lose face" if they knew my job.
6. My family's reputation would be compromised if they knew my job.
7. My husband or boyfriend would leave me if he knew my job.
8. My children would be ashamed of me if they knew my job.

HIV Testing Variables: HIV testing history were asked retrospectively. FSWs' testing history and their nonpaying partners' testing history (husbands and nonpaying boyfriends) were both included in the analysis. The questions used to measure the HIV testing behaviors were listed in.

Table 2-3: HIV Testing Related Questions

Subject	HIV testing related Behaviors Variables
Female Sex Worker	Have you ever been tested with HIV?
Husband	"Has your husband ever been tested with HIV?"
Boyfriends	"Has your boyfriend (no commercial sex exchange) ever been tested with HIV?

Other Demographic Variables

Age: FSWs' birth dates were collected in the questionnaire. FSWs' age were calculated by subtracting birth dates from interview dates.

Urban-Rural Residency: China has a distinct household registration system that regulates citizens' residence status. Populations are divided into two residence systems, urban residency, and rural residency. Social security and health insurance benefits are different based on their residency status. Therefore, residency status may have a significant impact

on FSWs' utilization of the local healthcare system. This variable was collected by asking whether the participant's residence registration was in the local city center (urban residency) or not.

Marital Status: FSWs' marital status was categorized as "never married/single", "married", or "divorced/widowed". The "divorced/widowed" category was specific to mid-age female sex workers since many of them started to engage in sex work because of divorce or widowhood.

Duration of Sex Work: FSWs were asked to estimate the length of their sex work. In general, an older FSW was more likely to have a longer history of sex work. But the variance inflation factor (VIF) analysis did not suggest strong collinearity between these two variables. Therefore, age and duration of sex work were both retained in the final models.

Education: FSWs' education status was categorized as "illiterate/no education", "primary school", "middle school", "high school/vocational school", and "associate degree or above". China has a 9-year compulsory education. Middle school is an important threshold for receiving an adequate education. Therefore, we further combined the categories and created a three-level education status, "primary or less," "middle school," and "high school and above."

Assessment of potential Bias

Selection Bias Selection bias is a bias of epidemiological design that occurred at the stage of recruitment. Selection bias will impact the internal and external validity of the study. In the case of our study, since this is not a random sample, participants' probability to be included in this study depends on their extended social networks. Individual RDS

weights are included in the data analysis to reduce the influence of different inclusion probability based on the size of FSWs' social networks. In addition, the FSWs who participate in this study are likely to be similar to each other. The data is not independently identical distributed (i.i.d.), which violates the basic statistical assumption. Therefore, in order to account for the selection bias, clustered standard errors are calculated based on each recruitment seeds.

Information Bias: For paper 3, the most important source of bias is information bias. The outcome variable, FSWs' HIV testing history, were collected based on self-report. Since FSW is a highly stigmatized population, FSWs are especially prone to social desirability bias. Previous studies have shown that FSWs would overreport their condom use and underreport their risky sexual behaviors in research studies (103,104). To reduce the potential reporting bias, we used a novel approach to validate our findings. Since the overreport of both condoms uses and HIV testing history are rooted in the same social desirability bias, FSWs who overreport their condom uses are presumably more likely to overreport their HIV testing history. Unlike HIV testing history, which cannot be verified objectively, recent condom use can be validated using a biomarker, prostate-specific antigen (PSA). PSA is not naturally produced by female bodies, and positive PSA results in vaginal swabs could signal recent unprotected sex. The study procedure was: FSWs who reported having sex within 24 hours of the questionnaire administered, received a PSA test. A positive PSA test suggested unprotected sex within 24 hours. The PSA results were compared with the self-reported recent sexual activities to identify the FSWs who honestly report their condom usage. The details and rationale of this research were reported previously (103). Among the 742 FSWs who reported having sex within 24

hours, 445 reported using condoms in their sex acts consistently, and 167 (37%) of them (445) had positive PSA tests. Only 575 (63%) of the FSWs correctly reported their recent condoms use. As we expected, among the 575 FSWs who correctly reported their condom use, 64.52% (371) reported having tested for HIV, compared to 70.06% (117) for FSWs who overreported their condom use status. This result indicated the existence of potential bias in FSWs' self-report HIV testing status. After eliminating the HIV positive individuals, a total of 562 FSWs were classified as a subsample of "honest" FSWs. A sensitivity analysis was conducted among the subsample.

Confounding bias referred to a noncausal association between a given dependent variable and an outcome resulting from the influence of extraneous variables. The confounding variable must be associated with both exposure and outcome variables and must not lie on the causal pathways between the two variables. For both paper 2 and paper 3, since FSWs' age, marital status, duration of sex work, education status, rural-urban residency and study sites were potentially associated FSWs' social network characteristics, HIV risk behaviors and collectivistic tendency, these factors were potential confounding factors for both studies. The identification of these factors was based on previous studies (46,71,116). The rationale of including these potential confounding variables was described in the measurement section as well. In addition to the above-mentioned variables, self-perceived control over condom use with clients, and partner's testing history were identified as potential confounders for Chapter 2 as well (70).

Chapter 3: The Application of Social Network Method for Female Sex workers in HIV/AIDS Research: A literature review of methodology.

Abstract

Background: Social network methods have been increasingly applied in HIV/AIDS research among female sex workers (FSWs). However, little research has assessed its methodologic weaknesses. The goal of this systematic review is to describe the current application of social network methods on HIV/AIDS studies among FSWs, identify the potential challenges and gaps in the literature.

Method: A systematic review was performed in publications that reported the application of social network analysis among FSWs. Eligible studies included studies with a network inventory in the data collection process.

Results: 12 eligible studies were identified and included in the final review. The synthesized evidence found that the sample collected for both sociocentric and egocentric network studies were localized. The analytic plan for sociocentric studies was limited to descriptive and bivariate comparisons. The discrepancies in network definitions and data collection increase the difficulties in collectively interpreting study results. Most of the analytic plan for egocentric studies were limited to behaviors on the individual level rather than the behaviors specific to their social ties.

Conclusions: The findings of this review enhance our understanding of interpreting the results of social network metrics in HIV studies among FSWs. We also make some recommendations for best practices in presenting findings from social network studies.

3.1 Introduction

As one of the most vulnerable populations for HIV infection, female sex workers (FSWs) carry a disproportionally high global HIV burden. As of 2018, 54% of the new HIV infections occurred among key populations like FSWs (117). In low-and middle-income countries, female sex workers are 13.5 times more likely to live with HIV/AIDS compared to the general female population (118). FSWs' clients are reported to have more relaxed attitudes toward unsafe sex and have a higher frequency of premarital or extramarital sex compared to the general populations. They are considered as the "bridge population" in the HIV epidemic for linking HIV infections from the high-risk population (FSWs) to the general female population (119). In China alone, commercial sex accounts for over half of the new HIV infections in the general population (23).

Commercial sex workers are at high risk for HIV infection and transmission for complicated reasons. Besides the fact that FSWs are more likely to engage in HIV high-risk behaviors (30,120,121), social networks play an important role in increasing female sex workers' vulnerability. As a socially marginalized population, female sex workers have limited choices in selecting their sexual partners and scarce resources that they can use to adopt preventive behaviors. Their primary sexual partners are individuals with multiple sex partners, intravenous drug users, or migrant workers, who are at heightened risk for HIV infections (122). This assortative social mixing pattern within these high HIV prevalence populations contribute significantly to their risk of HIV infection (123). In addition to the pattern of social mixing, social influence also shapes the FSWs' risk-taking behaviors. Peer support for condom use is significantly associated with consistent condom use in FSWs (121,124). A higher level of perceived social support, participation

of social groups, and social cohesion are positively correlated with the adoption of HIV preventive behaviors (19,35,83). A social network is crucial in delivering effective behavioral interventions for FSWs.

Although there are increasing number of social networks studies in investigating HIV transmission risk and preventive behaviors, few researches have applied social network methods. Social network requires network actor (node), the discrete individual or institution, and relational ties (edge/tie), and the linkage between a pair of network actors. As defined by Wasserman and Faust, "a social network consists a finite set or sets of actors and the relation or relations defined on them" (125). Social network studies provide useful information at three levels: the characteristics or behaviors of the nodes, the relational characteristic between any two nodes, and the relative structural position of the network actors. The analytic plan should take the inter-dependence at the three levels into consideration. Therefore, both sophisticated data collection methods and analytic techniques need to be used in a social network study.

There are two main types of social network studies, the whole network, and egocentric networks. The visualization of the two types of networks is demonstrated in Figure 3-1 and Figure 3-2.

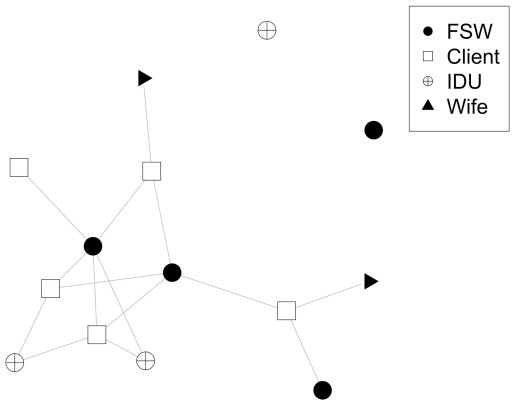


Figure 3-1: A Demonstration of a Sociocentric Network

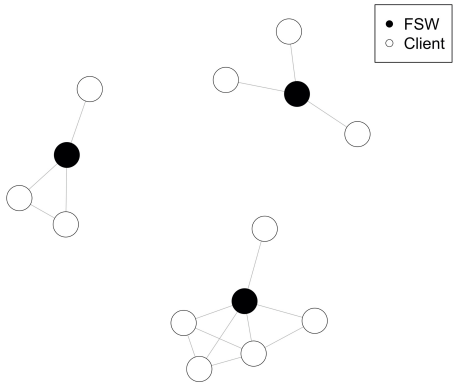


Figure 3-2: A Demonstration of 3 Egocentric Networks

Whole networks or sociocentric networks referred to social networks that contain all the network actors and relations within a predefined periphery. Sociocentric networks could provide the whole picture of a social environment and demonstrate how disease can be spread along with the network (125). The multitudes of the relational information in this type of study make sociocentric network data very difficult to collect. Thus, most sociocentric network studies are conducted within a small circle with a distinctive boundary, such as a classroom, workplace, or small islands (126,127). In sampling for men who have sex with men (MSM) or intravenous drug users (IDUs), all the network members are coming from the same population. However, sampling a complete sexual network for FSWs requires interviews with FSWs, their sexual partners, their clients, and the clients' sexual partners. This type of research design would put study participants at risk of disclosing their identity and sexual behaviors to other people, making it almost impossible to get consent from participants, especially FSWs' clients. Even if the complete sexual network could be collected, the network nodes and edges are intercorrelated. This would violate the independently identically distributed random variable assumption for most traditional statistical models. Therefore, unique analytical methods are essential to fully utilize the data from sociocentric network studies.

To overcome the difficulties in collecting data in the whole network, an increasing number of studies started to focus on the partial network of an individual, known as the egocentric networks. An egocentric social network is a subset of a sociocentric network that only consists of a focal network actor (ego), ego's social contacts (alters), and the social relationships among these network actors (edge/tie) (125). Compared to sociocentric social networks, the data of egocentric network studies is only collected through the focal network actor. In Figure 3-2, FSWs are the egos and the clients are the alters. In empirical data collection, the behavioral and demographic characters of alters are usually solely described by the ego (128). This method could significantly reduce the difficulties in collecting the whole networks while still retaining insights on the ego's immediate social environment. Unlike sociocentric networks, egocentric networks can be collected at a population level, increasing the external validity of the study. However, the information collected from these egocentrically collected network can be problematic. Most of the structural equivalence properties cannot be estimated. Since social relationships are derived from the ego's perspective and the relational information of alters are not observed, the relational information collected among the alters cannot represent the underlying social networks of the network actors.

Although social network studies could provide us with unique insights about the social dynamics in preventing the HIV/AIDS epidemic, this is still a relatively new approach. Some systematic reviews have assessed social networks and HIV outcomes. Both Shushtari et al. and Qiao et al. found that social support was positively associated with consistent condom use for female sex workers (16,19). Amirkhanian found that age mixing, seeking older sexual partners, and entering sexual networks increased MSM's

susceptibility to HIV infection (15). However, to my knowledge no prior systematic review has focused on the application of social network methods among female sex workers. Therefore, a systematic review is needed to summarize the current application of social network methods among FSWs in HIV/AIDS research and to critique the current network research approaches used in the collection of social network data and the analysis of network data.

3.2 Method

Searching Strategy

This systematic review was conducted in March 2020 using electronic search in major health science databases: PubMed, Web of Science, ScienceDirect, EBSCO (Medline), and ProQuest. Key journals such as Social Networks were also searched. The research period was not restricted, but all retrieved studies were conducted after 1990. References of related articles were manually screened for inclusions. The keywords used for the search were listed in **Table 3-1**. The Medical Subject Headings (MeSH) terms were used to define HIV-related studies. Within each database search, articles were initially filtered by language, human subjects and the age of the participants (>13 years old). All the retrieved citations were downloaded and imported to Mendeley Desktop (Version 1.19.4) for management. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the recommended flow chart were followed in conducting the systematic analysis (129).

Eligibility criteria

The eligibility criteria for articles include (1) studies with the sample population primarily comprised of female sex workers; (2) studies with at least one HIV-related outcomes or exposure, including HIV infection, risk behaviors, transmission risks or transmission mechanism; (3) studies using a network inventory or name generator to collect data at the social network level so that social network members can be uniquely identified in the data collection process; and (4) studies using network-specific analytic techniques to analyze social network data. Only English publications were included in the review.

Data extraction

The titles and abstracts were reviewed for to identify eligible studies. Articles were included for full-text review if titles and abstracts mentioned social network-related terms, such as “social networks,” “social cohesion,” “social support,” and “social influence”, and a primary study population of female sex workers. For full-text review, the method section was evaluated for network name generator or inventory. “A name generator is a survey item that asks respondents to name certain number of other actors with whom they share a particular type of social relation”(130). If studies did not indicate a specific network actor, they were excluded at the full text review. For example, Lippman and Kerrigan’s social cohesion scale measured FSWs’ social environment; however, this scale asked, “You can count on your sex worker colleagues if you need to borrow money,” or “You can trust the majority of other sex workers working in your area,” without indicating any specific network actor (101).

Analysis of literature:

After identifying the eligible studies, we assessed the sampling methods, network inventory used in data collection, defined network relations, and classified them into either sociocentric or egocentric networks. The research studies were organized in chronological order. For both sociocentric and egocentric network studies, we further identified the research questions, what kind of questions were answered with sociocentric network studies, sample size, network structural measurements, statistical methods, and main findings. We also summarized the network structural measurements used in these studies and compared the structural measurements results for egocentric networks.

3.3 Results

As presented in **Figure 3-1**, the flow chart of article selection recommended by the PRISMA, a total of 6891 articles were identified for review through keyword search and manual reference checks. During the initial screening of article titles and abstracts, 541 duplicated articles were identified, and 6013 articles were excluded from the following systematic review. These articles were excluded because they were not related to social networks, HIV/AIDS, or FSWs, in their titles and abstracts. Qualitative studies (except for mixed-method research), such as ethnography, were excluded in the screening too. After full-text review of 337 articles, 13 articles met the inclusion criteria and were included for the final review. Among the 13 articles, 1 article was excluded because the original article did not provide sufficient information with regard to data collection and network definition (131). The remaining 12 articles came from 8 unique research studies. Two studies were conducted in North America (132–136), four studies were conducted in China (77,115,137–139), one study was from Mexico (87), and one study was from Nepal (140).

Among the included studies, six articles from four original studies were whole social networks (133–136,138,139). Six articles from four original studies were egocentric social network studies (77,87,115,132,137,140). Felsher et al. took a subsample of a whole network study and performed analyses based on the egocentric network. Therefore, it was classified as an egocentric network study (132).

Sociocentric Network Studies

Among the identified studies, the Colorado Springs study collected multiple social relations among participants, including sexual relationships, needle sharing and general

social contact relations (133,134,136). Remple et al. and Liu et al. collected sexual networks (135,138) and Dong et al. collected a general social acquaintance network (138).

Data collection in Sociocentric Network Studies

In all studies collecting sexual network data, the "whole" sexual networks of FSWs were egocentrically constructed. These sexual networks included FSWs, their clients, and their sexual partners. Researchers only interviewed sex workers (or the HIV high-risk populations) and asked them to identify the names and the basic demographic variables (such as age, ethnicity, physical appearance, etc.) of their clients and sexual partners. If two FSWs nominated clients with the same name, age and similar physical appearance, researchers would consider these clients to be the same person. (133,135,138,139). No clients or the sexual partners' of FSWs (or the HIV high risk persons) were interviewed in these studies.

Dong et al. collected the general social contact (acquaintance) networks among FSWs by conducting one-on-one interview with each FSWs. 93 FSWs from 10 different workplaces were included in this study. Although the detailed network data collection protocol and the total number of FSWs in the 10 workplaces were not reported in the original study, this general social contact network was the most complete sociocentric network among all the studies (138).

The network boundaries were restrained to small towns such as Colorado Springs (132–134,136) or sex work establishments (135,138,139). Among all the studies, the Colorado Springs cohort had the largest sample size. A total of 111 FSWs were recruited in the initial study year (<50% of the total identified eligible participants), and 595

participants were enrolled in their final study year (133). All other sociocentric network studies had less than 100 participants in their studies and did not report their sampling fractions (what percentage of eligible participants were included in the study based on the total eligible participants in the defined boundary). For whole network studies, sampling fractions could indicate the internal validity of the statistical results.

HIV Related Measurements in Sociocentric Network Studies

As depicted in **Table 3-2**, the majority of the sociocentric network studies investigated the risk of HIV transmission within the sexual network and the engagement in HIV related risk behaviors. Perceptions of HIV infection risks were self-reported (135). HIV infection status was determined by serologic test (136). HIV risk behaviors were measured by self-reported risk behaviors such as needle-sharing (133,134,136), consistent condom use, unprotected sex (133,134,136), and knowledge, attitudes and practice toward HIV transmission control (138). In the longitudinal study, researchers found that HIV risk behaviors decreased over time and HIV transmission failed to spread through the risk-sharing network. During the four-year follow-up, only one HIV acute transmission occurred in this cohort (133,134,136).

Network Structural Measurements in Sociocentric Network Studies

Six out of seven articles used network structural measurements in their data analysis (132–136,139). The structural measurements were summarized in **Table 3-5**. There were three main topics of social network structures that are important for HIV studies in modeling sexual networks: First, it is important to consider the size of the network or degree centrality: the number of sexual ties an individual has (133–136). This measurement was used to estimate an individual's risk of acquiring the infection through

their sex partners in their networks. Individuals who shared risk behaviors with multiple partners were more likely to be infected. Second, identifying the cohesive subgroups in a larger network, including connected component, n-cliques, k-plexes, network density, reachability index (**Table 3-5**). In Colorado Springs studies, about half of the study participants were connected to a single network component (133,134,136). Remple et al. found all participants were linked together and form a large connected component (135). Because these study participants were linked through HIV risk behaviors, connected components were used to assess the potential of disease transmission through social interactions. They were also used to assess the level of social aggregation or "social foci," which potentially facilitate disease transmissions within or across their networks. Although a large number of the participants could be linked through risk-sharing networks, Rothenberg et al. only observed one acute HIV transmission throughout the four-year follow-up period (136). Third, research considered the potential network bridge that connected two cohesive subgroups. To consider some examples, Remple et al. used cut-vertex (135) and Liu et al. used betweenness centrality (139), to measure the "bridging" potential of certain network members to spread the disease from one cohesive subgroup to another. Both studies found that certain "regular clients" would visit multiple sex work venues and bridged the smaller networks.

Statistical Methods in Sociocentric Network Studies

The majority of the statistical analysis was limited to descriptive and bivariate comparisons (133–136,139). There was no consensus on which statistical tests for bivariate analysis. Rothenberg et al. and Remple et al. used nonparametric tests such as Pearson's rank correlation test and Mann-Whitney U test to compare structural

measurements to account for the non-normal distribution of these measurements (135,136). Liu et al. used parametric tests (139).

Dong et al. used a different approach in assessing social influences among FSWs. Z scores to assign FSWs' positions in HIV knowledge, attitudes, and practice domains. They calculated the conditional probability of FSWs' position in each domain based on their performance on other domains. For example, if an FSW had a higher score in HIV related knowledge, she would have a higher score in HIV related attitudes and practice. Dong et al. also measured the social influence of FSWs' social contacts by calculating the probability of an FSWs' position in two domains as a function of the position of the FSWs' social contacts in the one domain (138). For example, they claimed that for an FSW who had lower scores in HIV related practice, if she had more social contacts who had low scores in HIV practice, she would be more likely to have lower scores in HIV related knowledge and attitudes as well. However, these conditional probabilities cannot demonstrate the temporality in social influences. Therefore, such claim cannot be supported by their data. In addition, although the sociocentric network was constructed, the structures of the whole network were not included in the study (138).

Egocentric network studies

Data collection in Egocentric network studies

Four unique egocentric social network studies were identified in the literature research (77,87,115,137,140). Compared to sociocentric social networks, the sample sizes of egocentric network studies were relatively larger. The sample sizes of the two studies were over 600 (77,140). However, most of the participants in these egocentric network studies were recruited similarly as sociocentric network studies. Three out of

four studies used social network-based recruitment strategy, respondent-driven sampling, and snowball sampling as their recruitment approach (87,103,115,137). One of them used venue-based sampling for recruitment (140). These were the same strategies that sociocentric studies used to recruit their participants. The study participants were still mostly from the same area, belonged to the same social networks, and worked at the same venues. The improvements in sample diversity among egocentric studies relative to sociocentric studies were lower than expected. This indicated that the limitations in recruiting study participants were not because of the sociocentric networks but probably because of the difficulties in recruiting a marginalized population like FSWs.

HIV Related Measurements in Egocentric network studies

Egocentric network studies primarily focus on the potential effect of social influence on HIV behaviors (**Table 3-4**). Five out of six egocentric network studies focused on social support networks (77,87,115,137,140). Four out of the six studies assessed the correlation between FSWs' social network characteristics and HIV risk behaviors, including involvement of multiple risky behaviors (132), drug use (137), and condom use with clients (77,140), as primary outcome measurements. Wagner et al. and Guida et al. assessed the correlation between social stigma (drug use and sex work) with FSWs' social network information. Both studies found social stigma was negatively correlated with the size of the ego's social networks and the social support from their family members (87,115).

Network Structural Measurements in Egocentric network studies

As depicted in **Table 3-6**, egocentric network studies had different limits the size or number of alters an ego listed. Yu et al. and Deuba et al. allowed the egos to name up

to 15 and 9 alters, respectively (137,140). Studies without this restriction found that some FSWs reported more than 20 social contacts within their network (87,115). The upper limit of the network members could significantly alter network structural measurements. For example, an ego has nine interconnected social contacts and one independent social contact. The network density of the ego will decrease by 22% if the one independent social contact is included. These measurements should be interpreted with greater caution when we compared social network measurements in these fixed-choice studies.

As shown in **Table 3-4**, only one out of the six studies treated the egocentric network as a weighted network (137). In the real world, even with the same type of social ties, different relations often have different levels of strength or intensity. Yu et al. asked the ego to evaluate the tie strength among all pairs of alters as the network weights. The average network density from the weighted network was 0.04 (SD=0.19) (137), far away from the average network densities in the other studies without considering network weights, which were around 0.5-0.6 (87,115).

Another network structural measurement in egocentric network studies is network homophily. Network homophily measures the similarities between the ego and the ego's alters. Liu (2016) assessed age homophily by categorized ego-alter age difference as whether alter is older than ego, ego is older than alter, and ego-alter at the same age (reference) (77). Felsher et al. (2018) measured network homophily by calculating the proportion of each ego's network contacts who were of the same gender, ethnicity, and reported the same HIV risk behavior as the ego. Egos were further categorized as low homophilous (0% of the alters were from the same background), moderately homophilous (1%-19%), and highly homophilous (>20%) (132). Similar to previous

studies, racial and gender homophily was positively associated with the involvement of multiplex HIV risk behaviors and drug use (132,137). However, age and education homophily was not associated with use between FSWs and their sex partners (77).

Betweenness centrality and closeness centrality were measured in Yu et al.'s study. Betweenness centrality measured the "bridging potential" of the network ego, which was quantified by the degree to which the network alters were disconnected from each other (137). In general, higher betweenness centrality indicates that an ego has higher control over the information exchange between the network members. High betweenness centrality is also more likely to be observed among unstable and acquaintance networks (13). They found that drug using FSWs were more likely to have higher betweenness centrality, indicating that they are more likely to accept transient and short-term relationships than long-term relationships. Closeness centrality measured the number of the shortest path between a pair of network actors. In the case of egocentric networks, ego's closeness centrality is not very meaningful because the ego is connected to all the other alters by study design (88).

Statistical Methods in Egocentric Network Studies

Compared to sociocentric network studies, the analysis plans for egocentric studies are more complicated. Five out of six studies conducted regression analyses at the ego level (87,115,132,137,140). The primary outcome variables were the ego's risk behaviors. Social network characteristics, such as social support, and network structures, were added to describe the ego's social environment and to predict the ego's HIV risk behaviors. One study used the ego-alters' condom use status as the primary outcome variable. Multilevel logistic regression was used to account for the interdependence

between the alters. By doing this, the unit of observation was shifted from individual behaviors to ego-alter tie, which was the unit of observation unique to social network studies (77).

3.4 Discussion

In this systematic review, we identified both sociocentric and egocentric network studies to investigate HIV transmissions, and risk behaviors among FSWs. Most sociocentric social networks were constructed from egocentric interviews and the egocentric networks also failed to collect more diversified study samples. The statistical methods used in sociocentric networks were mostly descriptive and bivariate, and regressions were more likely used in egocentric studies. Researchers used sociocentric network studies to identify high-risk populations and transmission dynamics. Egocentric networks were used to study the risk behaviors of FSWs.

Sociocentric Network Studies

In most of the sociocentric networks, researchers identified large HIV risk-sharing networks (connected components). Sexual networks were also unstable and became less cohesive over time, which may create opportunities for the transmissions of HIV/STI to the general population (133–136,139). Male clients regularly jumped between FSWs' establishments (i.e., brothels) and created a potential bridge to spread the disease among FSWs (135,139). However, in both longitudinal and cross-sectional studies, HIV infections were not common even though there were known HIV positive individuals within the network (135,136). The spread of HIV within these sexual networks was limited, and no large transmission network was identified. One possible explanation is that safe sex practice has successfully halted the inward transmission within the network and HIV positive individuals were marginalized after the positive diagnosis. However, it is more likely that the network actors with the highest HIV risk did not participate in the study. Colorado Springs had more than 750 HIV positive individuals at the time of the

study, but only 19 of them were included in this high-risk network. The underlying HIV transmission dynamic was still unobserved.

All the sociocentric network studies used descriptive or binary hypothesis tests to analyze their data. These inferences were made at the whole network level rather than the individual level. For example, the connected components could identify the existence of subgroup structures in a network, but it cannot link certain demographic or social behavioral attributes to the subgroup membership. Social network specific models, such as exponential random graph models (ERGM) allow researchers to answer questions related to the tie-level information and account for the network structures explicitly. However, network inferences were very sensitive to missing values (141). Despite the efforts to collect complete network data, these sociocentric networks were only partially observed. Over half of the identified FSWs did not participate in the network study, not to mention the missing ties of their sexual partners (133). In this review, we found that the majority of the studies did not report the sampling fractions of the local high-risk community. Since missing ties are inevitable within these observed networks, reporting sampling fractions and the local epidemic profile could significantly increase the interpretability of the results.

Egocentric Network Studies

Egocentric network studies found that social stigma and high-risk behaviors were associated with a significant decrease of the size of FSW's social networks, especially the size of family and friends' network (87,115). However, the findings about the association between social networks and HIV preventive behaviors were inconsistent. Stronger social relationships and greater network homophily with risk-sharing contacts would increase

HIV risk-taking behaviors such as involvement in multiple risk behaviors and inconsistent condom use (77,132). General social support would decrease HIV risk-taking behaviors (140). However, FSWs with more cohesive social networks were less likely to use drugs (137). This discrepancy may result from different types of social networks, the different restrictions on the number of alters being named, and the inconsistency in network matrices used in the analysis. Researchers should be cautious in interpreting social network structural measurements when comparing the results for different egocentric networks.

The majority of the studies used the ego level outcome as the primary unit of analysis. Information collected through individuals' social networks were aggregated and treated as the individual's social environment as a whole. Although the social network data was collected at an individual level, individual information was not fully used in these studies. Research questions based on egocentric social networks could consider focusing on alter-level or ego-alter level outcomes. For example, multilevel logistic regressions may be considered in modeling tie-level outcomes (48,77). The downside of using multilevel regression is that it fails to incorporate the network structural features in the statistical analysis as it assumes that each alter is independent at the ego level. However, since most of the egocentric network studies recruited participants based on their venues or their social networks (i.e., respondent-driven sampling), there is a high probability that FSWs' sexual partners or clients may overlap and correlated. In addition, the design effects of the respondent-sampling scheme were not addressed in these studies. This could impact the validity and precision of findings as participants with larger

networks are more likely to be included. Future studies should be more careful in analyzing participants recruited from social network sampling frameworks.

Future Directions

This literature review identified several challenges in applying social network methods in FSWs research. Overall, the main challenges for social network studies among FSWs in HIV research were related to (1) the quality of data, due to legal and stigma concerns and non-random missing value patterns, and (2) the lack of appropriate analytical methods. There are several alternative methods to be considered.

When actual human to human social networks are difficult to describe, there are several alternative networks to be considered in future research. First, instead of social networks, biological networks, such as phylogenetic studies could be used as the proxy to construct social networks with greater precision. Phylogenetic studies could identify the virus genetic pairs by calculating the genetic distance of HIV or STI infections. This information could be an interesting add-on to the social network data. Second, online networks could serve as an alternative to the social networks in real lives. A few MSM studies utilize the Facebook network to study the association between online participation and HIV risk (12,142). Unfortunately, these types of data are difficult to collect from female sex workers because of ethical and stigma issues. Some studies attempted to use online networks and anonymity to model the client's behaviors and prostitution (143,144). However, since these data could not be linked to actual HIV risk and preventive behaviors, the risk for STI/HIV transmission within and across social networks could not be examined. Although most of the countries do not have online social network applications or forums explicitly for sex workers, a sizable FSWs had

been used dating websites and dating apps to solicit their clients. These online dating applications may provide a vehicle to collect social network data and data about the behaviors of FSWs. More importantly, online dating applications may also be a great place for social influence and behavioral interventions. Some MSM dating applications, such as Blued, had been piloted the delivery of HIV knowledge and preventive services through these types of dating applications (145). Studies in FSWs and heterosexual risk behaviors might also consider a similar approach. Third, several imputation methods and statistical frameworks have been proposed to remedy the missing value problems in social network analysis (146,147). However, because the information on FSWs' clients is most likely completely missing in the dataset, statistical methods could only provide limited help, and the results should be interpreted with greater caution.

Conclusion

This study provides insights on the complexity of applying social network methods in HIV research among FSWs. Social networks significantly influence the HIV transmission risk and health behaviors of FSWs, but the current social network studies have not been able to evaluate the influence effectively due to its limitations in the study designs and analytical methods. Future studies should consider combining data from different multitudes to supplement the unobservable information gaps in the current network designs in FSW research.

Table 3-1: Searching Strategy

	HIV Terms	Social Networks terms	Sex workers
	HIV	social network(s)	Female sex workers
OR	AIDS	network(s)	Commercial Sex workers
OR	human immunodeficiency virus	social network model(s)	Sex work
OR	acquired immunodeficiency syndrome	social network analysis	Prostitution
		Egocentric	FSW
		Sociocentric	CSW
		social support	
		social capital	
		sexual network	

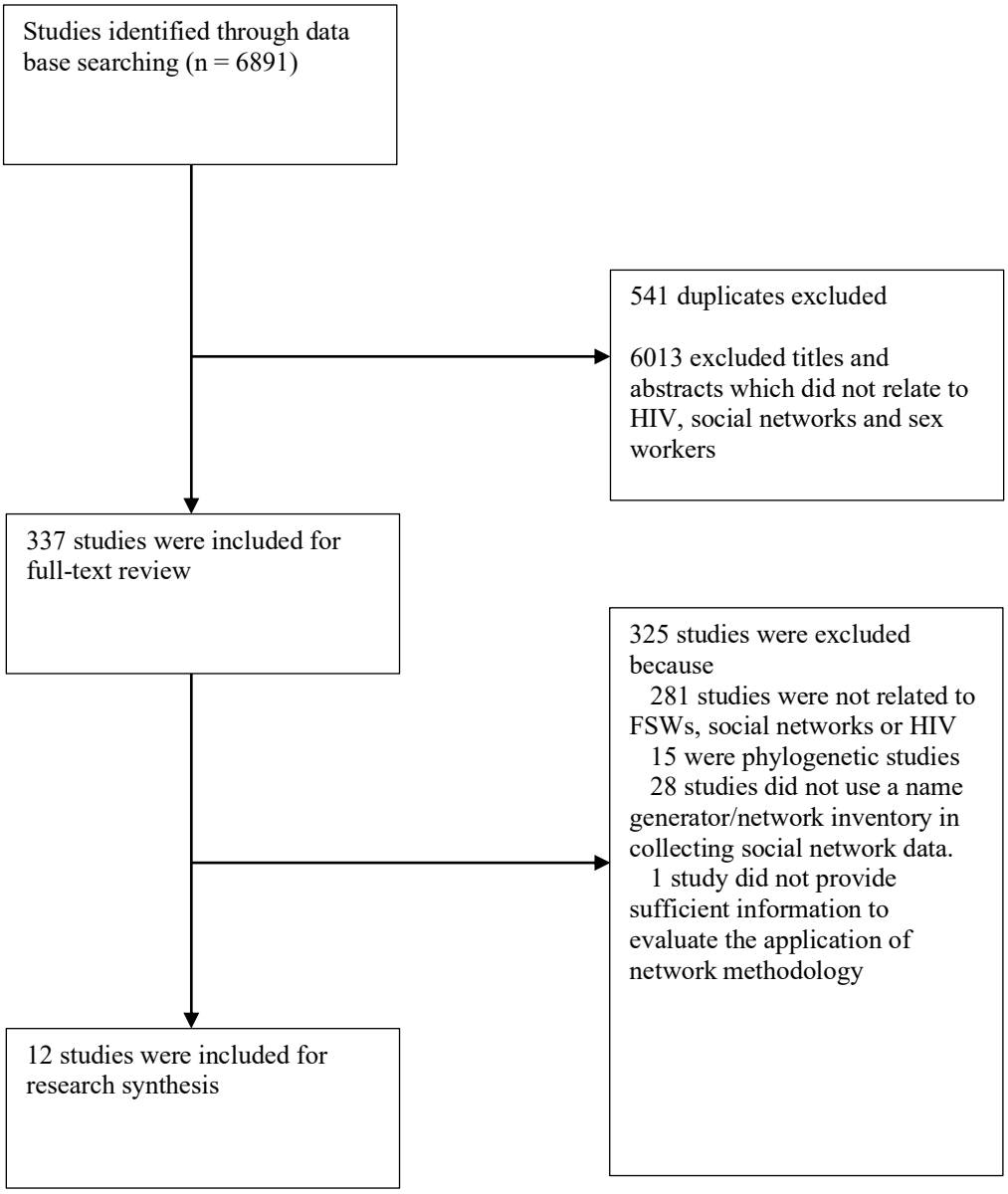


Figure 3-1: The Flow Chart of Article Selection and Extraction

Table 3-2: Summary of Social Network Data Used in HIV/AIDS Research

Study	Location	Study Design	Recruitment	Inventory	Relationships	Network Type
Woodhouse DE et al (133). Klovdahl AS, et al (134). Rothenberg RB et al (136). Felsher M, et al (132).	Colorado Springs, USA; 1988-1992	Longitudinal	Convenient sampling; Population enumeration;	Initial Network: sexual relations and contacts were identified through names; Follow Up Network: Personal Network identified by the initial members. Relational matrix between each personal network contacts were collected. Network contacts were matched by the researchers to construct the larger network, including the shared social contacts who were not interviewed.	HIV risk network: sexual, drug using, needle sharing and "any" social contact	Whole network; Constructed from egocentric interviews
Remple et al (127).	Great Vancouver Area, Canada; 2004-2006	Cross-sectional	Venue Based sampling	10 most recent sexual contacts including clients and noncommercial partners	Sexual contact	Whole network; Constructed from egocentric interviews
Yu et al (137)	Haikou, Shanghai and Beijing, China; 2008-2009	Cross-sectional	Respondent-driven sampling	"Meaningful or relatively important" social contacts; strength of alter-alter tie	Social contact	Egocentric
Deuba et al.(140)	Terai Highway districts, Nepal, 2012	Cross-sectional	Venue Based sampling	Social support questionnaire	Social support	Egocentric
Guida et al.(115) Liu H.(77)	Hefei, Nanning, Qingdao, China, 2014	Cross-sectional	Respondent-driven sampling	Chinese social network inventory	Social Support and sexual contact within social support network	Egocentric
Wagner et al (87).	Tijuana, Mexico 2012-2018	Cross-sectional	Sub-cohort; Snowball sampling	Egocentric individuals who provide various types of social support, including emotional, material, social participation, health advice, drug related, and relationship advice.	Social Support	Egocentric

Dong et al (138).	Yunnan, China 2014-2015	Cross-sectional	Stratified random sampling: using venue as primary sampling unit	Data was derived from ethnographical work.	Social contact	Whole network based on interviews;
Liu et al (131).	Xi'an City, Beijing, 2016-2017	Cross-sectional	Convenient sampling; Venue-based recruitment	Egocentric sexual relationships from the past 7 days; Male partners were matched based on nickname, age, marital status, occupation and province.	Sexual contact	Whole network; Constructed from egocentric interviews

Table 3-3: Sociocentric Network Studies: Study descriptions and results

Study	Article	Sample Size	Network Structural measurements	HIV related outcome/exposure	Statistical method	Main Findings
1	Klovdahl AS, et al (134).	First year: 111 enrolled participants (48 prostitute) and 1296 relations reported.	Network density, reachability index, component, Dyads, Triads, n-cluster	HIV risk behaviors: needle sharing behavior, unprotected sex	Descriptive	The study participants reported an average of 11.7 close personal associates (median, 27), higher than the national average. Half (600/1296) of the identified relationships comprised of a single network connected region (component). 1 (out of the 3) of the HIV positive individual was in the connected region. Within the connected region, the network density was low (0.016-0.018), the reachability index was 0.39 (about 40% of the social contacts could be reached at some length). The average distance between two network actors (i.e. mean length of shortest paths) was only three steps (3.1).
	Woodhouse DE et al (133).	Final year: 595 enrolled (133 prostitute) and 5894 relations reported.	Connected component from GRADAP	HIV risk behaviors: needle sharing behavior, unprotected sex	Descriptive	71% of the social network actors were connected to a single component. 58% of the HIV cases (11/19) were in in this single largest component and none of them occupy at the central position of the risk network.
	Rothenberg RB et al(136).	595 enrolled participants	Network stability, degree centrality, information centrality, n-cliques, k-plex	HIV risk behavior change; The change of transmission social network.	Bivariate Critical ratio, X^2 for goodness of fit to assess changes over time, and the Pearson's rank correlation to compare the stability index with network size.	Only 1 acute HIV infection was observed during the 4-year of follow up. The network was relatively stable for needle-sharing and drug use network, but the change of network was significant for social and sexual network. Over the four follow-up years, the number of connected components had increased, but the size of the largest connected components had been diminished. The mean degree centrality remained constant. Results from information centrality were inconsistent. Overall, diminution in network cohesion over the years.
2	Remple et al (135).	49 FSWs, named 205 clients	Component, cut vertex, k-core, clique, degree centrality, betweenness centrality, eigenvector,	HIV risk behaviors of clients of FSWs; self-perceived HIV infection risk	Bivariate Chi-square test, Fisher's exact test, Mann-Whitney U test	The complete network was composed of a fully connected component. Clients who visited more than 1 commercial sex establishments were the "cut vertex", the bridge to connect local sexual network. All reported HIV and STI infections occurred in high risk clients (clients who had multiple linkages to sex workers and establishments).

			information centrality			
	Liu et al (139).	66 FSWs and 680 sexual relationships	Degree centrality, betweenness centrality, and closeness centrality	HIV risk behaviors, consistent condom use;	Bivariate Chi-square test and t test.	Although most of the FSWs' sexual networks were isolated, some smaller networks were connected to make a big component. Regular clients served as bridge to connect local FSW sexual networks.
	Dong et al (138).	93 FSWs	N/A	Knowledge, attitude and practice towards HIV transmission and control	Z score to classify the FSWs based on their HIV knowledge, attitudes and practice. Using conditional probability to demonstrate the correlation between individual's response to knowledge, attitudes and practice.	The study found a strong positive correlation between individual's HIV knowledge, attitudes and practice. FSWs contacts are more likely to positively influence FSWs' knowledge and practice, but negatively influence their contacts' attitude. Overall, FSWs were more likely to be negatively influenced by their social contacts than the positive influence around them.

Table 3-4: Egocentric Social Network Studies

Article	Sample Size	Network Function	Network Structural measurements	HIV related outcome/exposure	Statistical method	Main Findings from Social Network
Felsher M, et al (132).	595 enrolled participants, 518 in model fitting	HIV risk network	Network Homophily Network size; Connected components (from sociocentric data)	Outcome: Involvement in multiplex social ties (two out of three, sexual contacts, needle-sharing or drug use)	Logistic regression at ego level	High degree centrality was related to engagement in multiplex risk behaviors. However, belonging to a larger component was negatively associated with multiplex risk involvement. Racial homophily increased the probability of engaging multiplex risk involvement.
Yu et al (137).	175 FSWs	N/A (general social contacts)	n-cliques, density, Closeness centrality and betweenness centrality	Outcome: HIV risk behavior: drug use	Logistic regression at ego level	Compared to non-drug users, drug users had significant less percentage of male alters and clients alters but have higher betweenness centrality and closeness centrality (Drug use FSWs were more likely to take transient clients than long-term clients).
Deuba et al. (140)	610 FSWs	Social support number score (SSQN); Social support satisfaction score (SSQS)	Network size (dichotomized into none and >1)	Outcome: HIV risk behavior: unsafe sex with clients	Logistic regression at ego level.	FSWs with a higher SSQN score were less likely to have unprotected sex compared to those with a low SSQN score. FSWs who were dissatisfied with their social support were more likely to have unprotected sex compared with those with a satisfied social support.
Wagner et al (87).	38 individuals. 19 FSWs and 19 of their primary sexual partners	Social support: emotional, material, social participation, health advice, drug related, and relationship advice	Network size Network density	Outcome: FSWs' social network Exposure: drug using stigma	Descriptive	FSWs and their partners internalized their drug-related stigma which lead to smaller kinship network.
Guida et al. (115)	1245 FSWs who were 35 years old and above	The Chinese Social Network Questionnaire (CSNQ)	Network size Network density	Outcome: FSW's social network; consistent condom use Exposure: sex work related occupational stigma	Linear regression at ego level	FSWs who perceived more sex work related stigma were more socially isolated and disconnected from their workplace network, had less friends, had smaller network, had less dense network and were less likely to trust their network contacts.
Liu H. (77)	1245 FSWs who were 35 years old and above	Sexual network within support network;	Network homophily	Outcome: condom use with sexual partner	Multilevel logistic regression at	FSWs were less likely to use condom with sexual partners who provided emotional or

					alter level and clustered by ego level	tangible support to them. Network homophily was not associated with condom use.

Table 3-5: Summary of Network Structure Measurements

Network Structural Measurements	Network Measurements	Interpretation
degree centrality Network size	the number of network actors to which an individual is directly connected with (136).	Sexual network: HIV infection risk Social support/general social contact network: the amount of social support and the level of social engagement
Connected Components	"A component is a subgroup of the network within which there is a path of some length from each person to every other person" (125,136)	Potential of disease propagation
n-cliques K-plexes (k-core)	A n-clique is a group of size n within which each person is connected to every other person in the group (136) A k-plex is a group of size n within which each person is directly connected to at least n - k members of the group (136)	Identify local cohesive networks.
Network Stability	"the proportion of all the named contacts who appear in a network at two timepoints, B/(A + C - B), where A represents the persons at time 1, C represents the persons at time 2, and B is the intersection of A and C" (136).	Network Stability
Network homophily	"to measure the proportion of a respondent's network associates who are of the same gender, racial background, and report the same HIV risk behavior as the respondent" (132).	To what degree members of a social network are like each other.
Cut Vertex	"An individual whose removal result in an increase in the number of components" (135).	The "bridge" between two sub networks. They could be the "bridging population" or the "super-spreader".
Betweenness	"Frequency with which an individual is on the shortest path between all other pairs of persons in a component." (135)	Higher betweenness centrality indicates higher level of "Bridging" potential. A "bridge" could connect high risk group with lower risk group. A network with high betweenness also indicates less redundant relationships.
Network Density	"The number of observed social ties over the total possible ties in a network" (125).	Network cohesion and sometimes could infer social cohesion

Table 3-6: Summary of Structural Measurements in Egocentric Network Studies

Article	Alter limitation	Weighted	Network Size	Network Density	Closeness	Betweenness	Note
Felsher M, et al(132).	None	No					
Yu et al(137).	15	Yes		0.04 (0.19) *	23.53(18.62)	2.86 (2.48)	Drug users:
				0.04 (0.02) *	17.86(14.54)	1.99 (2.21)	Non drug users
Deuba et al.(140)	9	No.	60(10%) of the FSWs had 0 social support provider. 550(90%) of the FSWs had more than 1 social support provider.		-	-	
Wagner et al(87).	None	No	5.0 (3-7) # Range: 3-15	0.60 # (0.33-0.71)	-	-	Female
			5.0 (3-7) # Range: 2-23	0.67 # (0.43-0.80)	-	-	Male
Guida et al(115). Liu et al(77).	30	No	3 (2-5) # Range: 0-18	0.5 # (0.3-0.8)			Support network (excluding sexual relationship)
			1(1-2) # Range: 0-6				Sexual network within support network

*: Mean (Standard Deviation)
#: Median (Interquartile Range)

Chapter 4: The More the Merrier: The influence of Social Support Networks on HIV Testing Behaviors among Female Sex workers in China

Abstract

Background

Promoting HIV testing among mid-age female sex workers in China is one of the most effective intervention strategies for curbing the HIV epidemic. The objective of this study was to investigate how social network factors potentially determining uptake of HIV testing among FSWs.

Methods

In this multi-center egocentric network study, respondent-driving sampling was used to recruit mid-age FSWs (i.e., 35 years old and older) from three cities in China. Logistic regression was used to assess the association between HIV testing behavior and social network characteristics.

Results

Among 1245 mid-aged FSWs, 62.24% (775) reported a history of HIV testing. Those who with a higher education were more likely to be tested for HIV. HIV testing was positively associated with prevalent syphilis infections (Adjusted Odds Ratio (AOR): 1.75; 95% CI: 1.38-2.24), HIV knowledge (AOR: 1.34; 95% CI: 1.15-1.57), partner's history of HIV testing (AOR: 5.92; 95% CI: 2.96-11.81), higher network transitivity (AOR: 1.77; 95% CI: 1.18-2.64) and inversely associated with network trust (AOR: 0.74; 95% CI: 0.56-0.97).

Conclusion

Increases in social cohesion may provide substantial support for HIV testing. Future HIV intervention program may be designed to form cohesive support groups to outreach FSWs and reinforce the adoption of HIV preventive behaviors.

4.1 Introduction

HIV Testing among Chinese FSWs

There is ample evidence that early initiation of antiretroviral therapy (ART) provides substantial benefits for people living with HIV, including lowering the level of viremia (148), increasing CD4 cell count (149), reducing AIDS-related illness (149,150), and decreasing the probability of virus transmission (151,152). However, the benefits of the treatment-as-prevention strategy depend on early diagnosis of HIV infection. Therefore, to maximize the benefits of this strategy, routine HIV testing among HIV key populations needs to be effectively implemented (151), especially among people at risk.

In 2018, China reported 1.25 million HIV cases with approximately 8000 new infections every year. Among these new infections, 69.6% were infected through heterosexual transmission (22), and over half of the heterosexual male incident cases were contracted through commercial sex (23). Among commercial sex workers, mid-age FSWs are at elevated risk for HIV infection and sexual transmitted infections (STIs). According to previous studies, younger FSWs in China usually enter the commercial sex industry in their early 20s and retire from commercial sex industry in their mid-30s to run small businesses (36), such as beauty parlor or clothing store. Younger FSWs typically charge more money for their sex services relative to older FSW and have more control to negotiate condom use with their clients (36). In contrast, older FSWs who stay in the commercial sex industry in their mid-30s are paid less for their services and usually carry a higher financial burden at home. Consequently, mid-age FSWs are less likely to negotiate condom use with their clients, and are less likely to participate in HIV intervention activities including HIV testing (31,32,34,36).

Despite the high burden of HIV infections, Chinese FSWs have low uptake of HIV testing; recent estimates suggest that only 16% to 48% of the women had ever received HIV testing in their lifetime, with estimates varying by geographic location (153–155). A growing body of literature has investigated factors that facilitate and impede HIV testing among FSWs. A conceptual framework based on the social ecological model suggests that factors at multiple levels within and around an individual promote or prohibit uptake of HIV preventive measures, including at the macro-level structural factors (e.g., legal, cultural, economics, etc.), meso-level factors such as workplace environment (e.g., venue policies, workplace violence, etc.), and social network (e.g., clients, partners, social support, etc.), as well as individual level factors (e.g., behavioral, education, age, etc.) (69,156). As previously reported, individual factors, including older age (155,157,158), higher level of HIV knowledge (59,155,157), higher level of perceived HIV risk (157,159) and duration of sex work (59,69) are positively associated with HIV testing among FSWs. Meso-level environment, including social relationships (46,59), work place support (70), higher perceived social support, social cohesion and participation [61,62], may promote the uptake of HIV testing. However, limited research has systematically examined how the role of social support embedded in social networks are associated with HIV testing among FSWs, especially mid-age FSWs in China.

The Role of Social Networks in HIV Testing

Although the association between social networks and HIV testing among mid-age FSWs had yet to be well studied, a sizeable literature reports that aspects of social networks are significantly associated with HIV testing among men who have sex with

men (MSM) (55,160–162). MSMs who had higher level of social/peer support (160,161), disclosed their sexual identity to social network members, and who had network member who engaged in HIV testing history (162) were more likely to be tested for HIV. Researchers hypothesized that the key influences of social networks are rooted in information support (e.g., providing network peers with information and knowledge related with HIV testing), emotional support (e.g., showing empathy, compassion and affirmation), and tangible support(e.g., providing them necessary financial assistance, material goods or services) from social network members (68,160).

Beyond network support, the shape/structures of social networks may influence behavioral adaptation (62). For example, people may be more likely to change or adopt a new behavior if their network is more interconnected and cohesive. Redundant signals from multiple network members could increase the likelihood of behavioral adoption (61). Similarly, dense networks where everyone knows each other fairly well are more likely to comprised of people with similar mindsets, providing strong emotional support through affection and affirmation. This quality is also called the "bonding" effect, which can deliver social support and social control efficiently (62,163). On the contrary, in a sparser and diversified social network, individuals are more likely to receive new information and more types of social support from people who are more distal from their own social circle, also known as "weak ties" (66,68). At the same time, the disconnection between the weak ties and individual's own social circle provides him/her with a structural advantage to control the information flow between the two parties, known as the "bridging potential" (164). Empirical studies indicate that MSM with a recent diagnosis of HIV are more likely to put themselves in a "bridging" position in their

support network to cope with the possible discrimination and stigma that resulted from HIV infection (13). In a sample of MSM from Detroit, Veinot and colleagues found that the functions of social networks, including generic social support and social norms embedded within social support network were not correlated with HIV testing; however, individuals with a diverse social network were more likely to be tested for HIV (55). Similar to MSM populations, FSWs are highly stigmatized and often have complicated relationships with their social networks (43,74,115). Investigating the influence of social networks on HIV preventive behaviors is important for informing network-level intervention strategies among mid-age FSWs.

This study fills a gap in the literature by taking the advantage of an egocentric social support network study design to further investigate the role of social support and social network structures on HIV testing among Chinese mid-age FSW. The egocentric social networks approach design is commonly used to study the effects of individual's personal networks (165). As a special form of social networks, egocentric networks consisted of an index person (ego) and ego's social contacts (alters). In this study, egos were mid-age FSWs and alters were FSWs' social contacts who would provide social support to them. The function of social networks was derived based on the amount of support each alter provided to his/her ego and the structures of social networks were derived based on the relations among network members. Using this egocentric network design, we were able to systematically examine the individual and social network factors that may promote or impede HIV testing mid-age FSWs in China. This study answered two questions: 1) What factors at the individual level were associated HIV testing uptake? 2) What factors at the social network level are associated with uptake of HIV testing?

4.2 Method

Data source

This multicenter egocentric study was conducted in 2014. Respondent Driven sampling (RDS) was used to recruit eligible participant. A total of 1245 participants were recruited from Hefei, Nanning and Qingdao. According to China Health Statistical Yearbook in 2019, the HIV incidence in Guangxi (Nanning) is 12.23 per 100,000, Anhui (Hefei) is 2.06 per 100,000 and Shandong (Qingdao) is 0.96 per 100,000 (106). Detailed data collection and recruitment protocols were described in previous publications (77,103,104).

Eligible participants were FSW who were at least 35 years old, had exchanged sex for money at least once a week in the past month and lived in Hefei, Nanning or Qingdao for at least 3 months prior to the interview. Demographic and behavioral variables were collected through structured interviews using computer assisted personal interview (CAPI). Upon enrollment, participants were screened for HIV and syphilis. Syphilis was screened using a qualitative immunoassay to detect antibodies to Treponema pallidum (Alere Determine TM TP test; Alere Medical Co., Ltd, Chiba Prefecture, Japan) and confirmed by a Treponemapallidum particle agglutination test for detection of antibodies to Treponema pallidum (TPPA; Fujirebio Inc., Tokyo, Japan or ABON Biopharm Co., Ltd., Hangzhou, China).

Ethics Consideration

The study protocol was approved by the Institutional Review Board (IRB) of the University of Maryland, Shandong University School of Public Health and local regulatory agencies including Guangxi Center of Disease Control and Prevention, and Hefei Center of Disease Control and Prevention. Written informed consent was obtained

for all the participants. Each eligible participant received interviews by trained interviewers using computer-assisted personal interviewing (CAPI) in a private room near the proximity to participants (less than 1 h-travel time). The identities of the study participants were protected, and no information collected in CAPI could be used to identify study participants. For taking part in this research study, FSWs were paid for their time and inconvenience in the amount of up to $18.5 ($9.5 for receiving an interview and $9 for introducing 3 friends to participate in this study). The research datasets were deidentified for data analysis and manuscript preparation.

Dependent Variables

HIV Testing Status: FSWs were asked to report their history of HIV testing by answering "Have you ever been tested for HIV in your lifetime?". Since this was a cross-sectional study, we did not collect information regarding repeated testing.

Independent Variables

Testing Status of FSW's non-commercial sexual partners: FSWs were asked about the HIV testing history of their current husbands or boyfriend (no commercial sex exchange). The variable was coded as (0) never been tested; (1) boyfriend/husband has been tested; (2) partner's testing status unknown; and (3) no stable sexual partner;

Self-Reported Condom Use with Clients: Condom use with clients was measured using a 7-item scale that assessed condom use with clients in the last month under different scenarios (e.g., frequency of condom uses when clients gave incentives for condomless sex; condom use when clients had erectile dysfunction; or frequency of condom-less sex due to unavailability of condoms). Each response was measured on a 4-point Likert scale

ranging from (0) never happened to (3) always happened. A higher score indicates more frequent condom use. The Cronbach's alpha was 0.78, and scores ranged from 0 to 21.

HIV Knowledge: Knowledge regarding the modes of HIV transmission was measured by 11 true or false questions (e.g., you will be infected if your food is prepared by a HIV positive person). One point was given for each correct answer. The range of this variable was 0-11, with higher score indicating greater knowledge.

Egocentric Social Support Networks

The Chinese Social Network Questionnaire (CSNQ) was used as the network inventory in this study (86,112). Name-generator was used to ask mid-age FSWs (egos) to list, by giving the pseudonyms, alters who would provide them social support. Each ego could name up to 30 alters. Alters could be friends, family members, relatives, pimps, venue owners, other FSWs, or other individuals whom the respondents knew for at least 1 month. Six items were used to define the egocentric network of an ego(166). Egos were asked to list alters who would: (1) lend them 200 Chinese dollars ($30 US); (2) take care of the them, if they were confined to bed for 2–3 weeks; (3) help or advise the them if the they had problems regarding family or health issues, (4) agree with or support their ideas or actions; (5) make them feel respected or admired; or (6) convince them to confide in the alter. Each response was measured on a four-point likert scale: (0) definitely will not provide, (1) probably will not provide, (2) probably will provide, (3) definitely will provide. The ego's social network was inclusive of all individuals who were perceived to provide at least one of the six types of social support to egos. Social demographic information about the alters was collected from the egos, including the alters' age,

education, marital status, and relation to the ego. No alter was interviewed in the data collection process.

Social Support: The above six-item measure for social support covers tangible support (items 1–3) and emotional support (items 4–6). The level of social support perceived by each ego was the sum score of each social support item. The range of social support from each alter is 0 to 18. Each ego can name up to 30 alters.

Social Network Structures: Each ego was asked to identify whether each alter knew each other and generated a relational matrix according to their relationships. The types, strengths and direction of the alter-alter relationship were not measured as egos may not know such detailed information about their alters. Five network structural measurements were used in our study.

Network Size was measured by the number of alters in an ego's social support network. We used three measurements to quantify network cohesion, network density, constraints and transitivity. *Network density* was the proportion of observed ties over the total possible ties in a network (ranged 0-1) (48). A network with a high density indicated the higher proportion of the interconnectedness between network members. This measurement has been widely used in the network literature (55,167,168). *Transitivity*, referred to whether "friends of my friends are also my friend" (169), was the number of observed triads (a group of three people all know each other) over the possible triads (the total number of three-person group) in a social network. A network with high transitivity indicated high reciprocity in the network. A highly transitive network would reinforce network influence and strengthen the emotional support. *Network Constraint* of ego was a Burt's structural hole index which measured the redundant ties around egos. It measures

how much egos' alters are interconnected with other alters (164). An ego's network with less alters (i.e., ego would invest more on each alter) and more interconnected alters has a higher level of network constraint. An ego's network with more alters and less common connections among alters has a lower level of network constraint. Although both transitivity and constraints measured cohesive network, network constraints decrease as network expand, opposed to transitivity which increases as the network expands.

Effective Size was another Burt's structural hole index which measures the diversity of a social network. It referred to the number of nonredundant ties in a network. If an alter was completely disconnected with other alters in an egocentric network, this ego-alter tie was considered nonredundant. Nonredundant ties in a support network could provide unique and independently acquired resources to the ego. However, more nonredundant ties in a social network usually suggested a lower level of social cohesion. Effective size was calculated as the number of alters minus the average ties of alters within the ego network, not counting ties to ego (164,170).

Network Characteristics:

Average alter trust: Egos were asked to rate the level of trustiness to each alter on a 5-point Likert scale: (0) Do not trust at all; (1) Do not trust; (2) Do not care; (3) Trust; (4) Very trust. The average alter trust is the average rating of all the alters in ego's network.

Average alter closeness: Egos were asked to rate the level of closeness to each alter on a 3-point Likert scale: (0) Not close; (1) Average; (2) Close. The average alter closeness was the average rating of all the alters in ego's network.

Statistical Methods

Network structural measurements were calculated using R package igraph(version 1.2.4.1) (171). Descriptive analysis was performed to describe the mean and standard deviation of continuous variables and proportions of categorical variables. Chi-square and t tests were used to examine the association between behavioral variables and HIV testing status. Mantel-Haenszel tests were used for ordinal independent variables such as education status. Since respondent driven sampling was used for participants recruitment, RDSanalyst(version1.8-6) was used to calculate the survey weights. Rao-Scott Chi-Square tests and weighted linear regression were used to obtain the RDS adjusted p-value.

Multiple logistic regression models were used to assess factors associated with HIV testing status. HIV testing status was used as the dependent variable in all models. Based on previous literature and using a model-building approach that considered individual-level and network characteristics sequentially, we explored the potential individual-level predictors of HIV testing in Model 1. We subsequently added partner level predictors including FSWs' self-reported condom uses with their clients and their nonpaying partner's HIV testing status in Model 2 and Model 3. To avoid over fitting the models, we removed HIV knowledge and syphilis status from Model 2 and Model 3.

For models to examine social network variables, we fitted social network variables separately as social network variables were highly correlated (Table 4). Each social network variable was estimated as separate models. Across these models, Demographic variables including age, education, marital status, migrant status, duration of sex work and city were adjusted as potential confounding effects. The crude odds ratio (COR), adjusted odds ratio (AOR) and their 95% confidence intervals were used to

estimate the strength of the associations. Akaike information criterion (AIC) and Bayesian information criterion (BIC) were reported to assess model fit. To account for multiple comparison bias in social network measurements, Bonferroni corrected alpha level is considered for statistically significance (alpha = 0.006). RDS weight was adjusted in regression analysis to account for the nonrandom sampling method. SAS University Edition was used for regression analysis. R (version 3.6.1) and Rstudio (version 1.0.143) were used for data management and estimation. All Since an HIV positive diagnosis could substantially change an individual's social networks, we excluded the ten HIV positive FSWs from regression analyses. Since network structural variables were not defined when the network size was zero, three FSWs who reported no social contacts were excluded from the regression analysis.

Sensitivity Analysis: We examined the internal validity of this study by running two additional analyses. (1) To address the potential self-report bias that FSWs are known to overreport their use of HIV preventive (103,104,172), we used a novel approach (a prostate-specific antigen test) to validate our study results. (2) To address the potential confounding effects of types of social networks, we divided the perceived social support variable by the ego-alter relationships and examined whether the association between perceived social support and HIV testing uptake differed based on who was providing the support. The rationale and details of the sensitivity analysis are provided in **Appendix**.

4.3 Results

Descriptive Analysis

A total of 1,245 mid-age FSWs were recruited from three cities in China: (418 in Nanning, 407 in Hefei and 420 in Qingdao. As depicted in **Table 1**, 62.24% (775) of the FSWs reported a history of HIV testing. FSWs who were older, worked longer as FSWs, and had a higher level of HIV knowledge were more likely to receive HIV testing. About half (51.72%) of the unmarried FSWs were ever tested for HIV, compared to 61.5% among married FSWs. FSWs' testing status was highly associated with their partner's; 88.1% of the FSWs who had partner with a history of HIV had been tested with HIV, but 60% among FSWs whose partners did not receive HIV testing. Over 70% of the FSWs in Qingdao and Nanning were tested for HIV, but less than 40% of t FSWs in Hefei had HIV testing history. FSWs with a history of HIV testing had slightly larger network size (4.81), more social support (53.67), but less network trust (2.95) and network closeness (1.57) compared to those who did not have a history(network size: 4.45; social support:51.32; average trust: 2.95; average closeness: 1.59), although the results were not statistically significant in bivariate comparisons. Higher network transitivity was significantly associated with FSWs' HIV testing. As depicted in **Table 2,** total support, network transitivity, size, trust and closeness were significantly positively correlated with each other. Effective size was positively correlated with network size but negatively correlated with network density, as opposed to ego's constraint.

In multiple logistic regression analysis (**Table 3**), FSWs who had higher HIV knowledge (AOR=1.34; 95% CI: 1.15-1.57), had prevalent syphilis (AOR: 1.75; 95% CI: 1.38-2.24) were more likely to be tested with HIV. At partner-level, FSWs who frequently use condoms with their clients (AOR=1.06, 95 % CI: 1.01-1.11) and FSWs

who had at least one stable partner were more likely to be ever tested for HIV (AOR=5.67, 95 % CI: 2.67-12.50) were more likely to be tested for HIV themselves.

When the social network factors were added in a multiple regression (**Table 4**), total social support was not associated with HIV testing. Among network structural measurements, egos who had highly transitive social networks were more likely to be tested for HIV (AOR= 1.77; 95% CI: 1.18-2.64). FSWs who had greater trust in their social networks had lower odds or HIV testing (AOR= 0.74; 95% CI: 0.56-0.97). Network size, constraint, and density were positively associated with HIV testing l (AOR= 1.07; 95% CI: 0.99-1.15; AOR=1.17; 95% CI: 0.58-2.24; AOR=1.44; 95% CI: 0.87-2.39; respectively), although the results were not statistically significant.

Sensitivity Analysis: The detailed results of sensitivity analysis were reported in **Appendix**. Prevalent syphilis infection, HIV knowledge, and partner's testing status maintained significant associations with HIV testing status. Network transitivity and density were maintained positive associations HIV testing among FSWs with relatively large effect size, although the results were not statistically significant. Results from the sensitivity analysis were consistent with the main analysis.

Social support from family and friends were not associated with FSW's testing status and support from distant relatives, boyfriends and clients had negative impacts on FSW's HIV testing behavior. The substantial effects of these social support were very small.

4.4 Discussion and Implications

There are three main findings from this multicenter egocentric network study: 1) uptake of HIV testing among FSWs had been significantly improved compared to previous research (153–155); 2) Uptake of HIV testing was positively associated with HIV knowledge, syphilis infection, partner's testing status and condom use with clients; and 3) mid-age FSWs with larger and denser social networks were more likely to be tested with HIV. Although some variables were not statistically significant in sensitivity analysis, the direction of the study results were consistent.

In our study, 62% of FSWs had been tested for HIV, significantly better than the previous reports, 17.7% in Yunnan, surveyed in 2011 (153), and 35.9% in Guangxi, pooled surveys in 2012-2015 (73). The testing uptake varied in the three study sites. The FSWs testing uptake in Nanning and Qingdao were over 72% but this number was only 40% for Hefei. Although, the reasons for the difference are not know, this was probably due to the different levels of government efforts in HIV control. Qingdao, as a more economically developed city with fairly good public health infrastructure, and Nanning, as a city with high HIV prevalence due to the historical drug trafficking, had more government efforts put in HIV control than Hefei. It is also possible that mid-age FSWs in Hefei did not perceive risk for HIV infection, compared to FSWs in other two cities. This finding indicates that uptake of HIV testing in China is heterogonous in China and a large-scale of promotion campaign should be continued among this vulnerable population, especially in the areas with low HIV testing, such as Hefei.

Our study highlighted the importance of STI control in HIV screening. FSWs with previous syphilis infections were significantly more likely to be tested with HIV. This might be through two possible pathways: 1) STI infections may serve as the

"warning" sign for individuals with risky behaviors and motivate them to receive HIV testing (109); 2) In China, when an FSW is tested and treated for a STI, her doctor may encourage her to screen for other STIs, including HIV. For either pathways, the increasing utilization of healthcare services due to STI increases the uptake of HIV testing.

In this study, we found low uptake of HIV testing among FSWs' non-paying partners (i.e., current husband or boyfriend). Only 10% of FSWs' reported that her current partner had ever been tested for HIV. Among FSW with husbands, 17.08% of FSW reported that their husbands had sexual partners but only 6% of them reported consistent condom use with their husbands. Among FSW with non-paying boyfriends, 32.6% reported that that their boyfriends had other sexual partners, but only 19.37% of them reported consistent condom use with their boyfriends. Without knowing their HIV status, a large number of the FSWs' steady partners were at high risk of HIV infections, but they were not aware of their risk and could potentially spread the infections to the general populations. FSWs' stable partners should be considered as the key populations for HIV infections and should get more attentions in HIV testing programs or campaigns It is possible that information bias exists when FSWs reported the HIV testing status of FSWs' nonpaying partners. However, we believe it's important to draw attention to this critical, yet under researched population.

Self-reported condom use with clients was positively associated with HIV testing in our main analysis, (AOR= 1.06; 95% CI: 1.01-1.11). However, the magnitude of the effect was attenuated among FSWs who correctly reported their condom use status in our sensitivity analysis (AOR= 1.02; 95% CI: 0.96-1.08). Although the substantial change of

the result was small, potential self-reported bias may exist and it could change the conclusion we draw from this type of information.

Different from previous studies (69), social support was not associated with HIV testing behavior. Although contrary to our hypothesis, this result was not surprising. The mechanism of how social support influences individual's health is through "buffering perception of stress, providing specific care and supports, influencing help-seeking through transmitting social norms and values, and acting as referral agents to professional services" (173). Social support is especially useful in dealing with sudden and stressful life events (174). However, HIV testing and other preventive behaviors, such as condom use, may be less associated with buffering against stress and often required minimum social care, especially when FSWs were unwilling to disclose their identity to their main support sources, family, relatives and friends. Social support network was considered as multiplex social networks (i.e. those composed of multiple relationships). Multiplex social networks are more likely to deliver tangible social support that may not be effective social support (173). HIV preventive behaviors were more directly influenced by the social norms and social expectations of the social networks than the total amount of perceived social support (55). In prior research, social support from different sources may have different effects on FSWs. However, our sensitivity analysis, although some social relations provided negative impacts to HIV testing, overall, the association between social support and HIV testing was small (Appendix Table 3).

Although social support was not associated with HIV testing behavior in our study, social structures were associated with FSWs' HIV testing uptake. We found that FSWs with larger and close-knit social support networks were more likely to adopt HIV

preventive behaviors. This finding was consistent with previous literature and social network theories (52,55). Social network structures could directly influence how social support and social influences were perceived by FSWs. As shown in other studies, individuals with larger social networks are were more likely to have higher level of psychological well-being, and to adopt HIV preventive behaviors (55,74). Members of a dense network were also more likely to agree on the network expectations about their behaviors, conform and support each other (163). In multiplex social support networks, denser networks were more likely to be family and friends' network which usually facilitated positive social influence, compared to sparser networks which were more likely to be dominant by their sexual partners. As presented in **Appendix Table 3**, after controlling for the amount of social support, transitivity and network size were still significant predictors for HIV testing. This indicated that among the FSWs who perceived the same amount of social support, FSWs with larger and denser social networks were more likely to have tested for HIV. Therefore, instead of the total amount of social support, social network structures were more likely to capture the "affective" social support and network transitivity was stronger predictor for HIV testing behaviors among mid-age FSWs in China.

In contrast to common intuition, individuals who had greater trust and more intimate with their network were less likely to be tested for HIV. Based on previous studies and network theories, individuals tended to have greater trust in their "strong ties", and strong ties were their interconnected social connections (66). However, in our study, the average network trust and average network closeness were only weakly correlated with social cohesion. They are also negatively correlated with the network

size. It is possible that the greater trust towards FSWs' social network hindered their ability to receive new information and limited their social interactions with the larger community (175). Since we did not explicitly ask the HIV testing norms among FSWs' social networks, if FSWs' social contacts had negative norms towards HIV testing, stronger network influence would lower FSWs' willingness to be tested for HIV (52). Future studies are needed to disentangle the underlying mechanism of the social influences on HIV testing behaviors among FSWs.

Out study makes an important contribution to analysis methodology in egocentric social networks. Previous studies found associations between network structural measures and HIV preventive behaviors. Veinot et la. found no association between proportion of strong ties and HIV testing behaviors (55). Choi et al. found positive association between network density and protected anal intercourse (52). In our network measurements, as presented in Table 2, the standardized network cohesion measurement (i.e., network density) was negatively associated with network size, consistent with previous research (176). For example, a network with only one social contact had network density (ranged 0-1) of 1. Therefore, if we used network density as our measurement for network cohesion, the effects of network cohesion might be attenuated by the negative impact of smaller network size. This effect was especially prominent in our study because we did not limit the number of social contacts our ego could list in our network inventory as the above-mentioned studies. Therefore, in future egocentric social network studies, researchers should carefully choose the different network structural measures to use in statistical analysis.

Strengths and Limitations

There are several strengths in this study. (1) We used respondent-driven sampling to identify and collect data on "hidden" population. (2) The effects of social networks are difficult to disentangle, but we used several social network measurements to improve the reliability of our findings and the results were consistent with different measurements. (3) We used a novel method to reduce the potential self-report bias in our study. Since self-reported history of HIV testing could not be validated using an objective method, we used a similar self-report variable that could be validated through a biomarker to identify potential self-report bias in our data. Our study results were relatively consistent in the subsample. Although the self-report condom bias may not be directly linked to self-report testing bias, it is a related verifiable self-report bias indicator to validate the robustness of a variable that cannot be verified.

There were two main limitations of this study. First, this was a cross-sectional study, and we only collected the information on HIV testing in FSWs' lifetime, so there is a temporal ambiguity between the predictors and the outcome variables. Second, all of the demographic and behavioral information of the FSWs' alters were collected through the ego. Alters were not interviewed as part of this study, therefore reports may be prone to information bias. Egos reporting about alters is common practice across egocentric network studies (128), and it would be impractical to interview the people around FSWs because FSWs tend to conceal their identity in front of their family and friends. Although respondent-driven sampling method is considered as one of the best strategies to recruit marginalized populations, the recruited sample is still intercorrelated, which can inflate the Type I error rate.

Implications to intervention

The findings of this study may inform the development of social network interventions that promote HIV testing for mid-age FSWs in China. This study further emphasizes the importance of social influences and informational support rather than simply providing the necessary resources for them. For example, in addition to training peer educators and social workers to disseminate tangible and informational social support, it is more important to design and encourage FSWs' participation in their own social groups. By increasing the social participation and social connection of FSWs, we could be more effectively promote HIV preventive behaviors among this high-risk population to curb the overall HIV transmission in China. Designing psychoeducation intervention from a social network perspective could also holistically improve the overall health conditions and psychological well beings of mid-age FSWs in China.

Table 4-1:Survey participant demographics and risk behavior (n = 1245)

Continues Variables	HIV Testing Status Never (N=470)	Ever (N=775)	P value	RDS P-value
Age	39.93(5.30)	40.15(5.52)	0.48	0.96
Duration of sex work (years)	3.35(3.37)	4.61(3.54)	0.00	0.08
HIV Knowledge	7.27(2.82)	9.10(2.03)	0.00	0.00
Occupational Stigma	16.56(2.96)	16.30(2.82)	0.12	0.45
Condom Use with Clients	13.69(3.55)	14.56(3.00)	0.00	0.18
Social Network Measurements Function				
Total Support	51.32(27.90)	53.67(32.12)	0.17	0.76
Structure				
Effective Size	2.83(1.72)	2.86(1.65)	0.76	0.91
Constraint	0.57(0.25)	0.57(0.23)	0.79	0.49
Transitivity	0.62(0.35)	0.68(0.66)	0.01	0.04
Density	0.50(0.35)	0.54(0.32)	0.03	0.14
Network Size	4.45(2.37)	4.81(2.32)	0.03	0.14
Network Characteristics				
Average Trust	2.98(0.57)	2.95(0.61)	0.44	0.13
Average Closeness	1.59(0.39)	1.57(0.39)	0.41	0.70
Categorical Variables				
Marital Status				
Unmarried	56(48.28%)	60(51.72%)	0.01	0.42
Married	237(38.85%)	373(61.15%)		
Divorced/Widowed	177(34.10%)	342(65.90%)		
Education				
Primary or Less	234(42.86%)	312(57.14%)	0.01	0.00
Middle School	194(33.62%)	383(66.38%)		
High School	42(34.43%)	80(65.57%)		
Residency			0.00	0.53
Urban	170(44.74%)	210(55.26%)		
Rural	300(34.68%)	565(65.32%)		
Risk Behaviors				
Partner HIV Testing			0.00	0.00
Never	304(39.28%)	470(60.72%)		
Ever	13(11.93%)	96(88.07%)		
Unknown	64(43.24%)	84(56.76%)		
No Partner	89(41.59%)	125(58.41%)		
Syphilis Infection			0.26	0.46
Yes	101(34.95%)	188(65.05%)		

No	369(38.60%)	587(61.40%)		
City			0.00	0.00
Nanning	118(28.23%)	300(71.77%)		
Hefei	247(60.69%)	160(39.31%)		
Qingdao	105(25.00%)	315(75.00%)		

Table 4-2:Pearson's Correlation among Network Measurements

	Total Support	Effective Size	Constraint	Transitivity	Density	Network Size	Trust
Effective Size	0.59	-					
Constraint	-0.53	-0.81	-				
Transitivity	0.21	-0.33	0.43	-			
Density	-0.08	-0.67	0.78	0.74	-		
Network Size	0.87	0.75	-0.67	0.19	-0.18	-	
Trust	0.25	-0.11	0.14	0.12	0.17	-0.02	-
Closeness	0.20	-0.11	0.14	0.09	0.16	-0.04	0.57

All correlation results were statistically significant and smaller than 0.004

Table 4-3:Multivariable Logistic Regression without Social Network Factors (N=1234)

Variables*	Model 1	Model 2	Model 3
Individual Level			
Age	1.01(0.95-1.08)	1.00(0.94-1.07)	1.00(0.95-1.07)
Education			
Primary or Less	Reference		
Middle School	1.12(0.86-1.47)	**1.39(1.13-1.71)**	**1.33(1.07-1.65)**
High School or above	1.29(0.71-2.33)	**1.63(1.03-2.59)**	1.44(0.90-2.30)
Marital Status			
Unmarried	Reference		
Married	1.39(0.66-2.94)	1.28(0.68-2.40)	0.97(0.51-1.83)
Widowed/Divorced	1.32(0.66-2.64)	1.33(0.75-2.33)	1.33(0.71-2.48)
Residency: Migrant Vs. Local	0.92(0.53-1.57)	0.98(0.57-1.68)	0.97(0.57-1.65)
Duration of Sex Work	1.00(0.93-1.07)	1.02(0.95-1.1)	1.01(0.93-1.10)
HIV Knowledge	**1.34(1.15-1.57)**		
Prevalent Syphilis	**1.75(1.38-2.24)**		
Partner Level			
Self-Reported Condom Use with Clients		**1.05(1.00-1.11)**	**1.06(1.01-1.11)**
Nonpaying Partner's HIV Testing Status			
Never tested for HIV			Reference
Have tested for HIV			**5.92(2.96-11.81)**
Unknown			0.82(0.45-1.50)
No Partner			0.56(0.16-3.47)
City			
Qingdao	Reference		
Nanning	0.56(0.14-2.24)	0.77(0.16-3.68)	0.75(0.16-3.47)
Hefei	**0.19(0.04-0.85)**	**0.22(0.05-0.99)**	**0.29(0.05-0.90)**
DF	11	10	13
-2loglik	2591.07	2852.703	2765.16
AIC	2615.07	2874.703	2793.16
BIC	2684.18	2938.056	2873.79

*Variance inflation factor (VIF) was used to asses potential multicollinearity among the independent variables. No significant multicollinearity problem was found in the models.

Table 4-4:The Association between HIV testing and Social Network Characteristics

Main independent Variables*	COR (95%CI)	AOR* (95%CI)
Function		
Total Support	1.00(0.99-1.01)	1.00(0.99-1.01)
Structure		
Effective Size	1.01(0.90-1.14)	0.99(0.90-1.09)
Constraint	1.05(0.54-2.03)	1.17(0.58-2.24)
Transitivity^	**1.72(1.08-2.76)**	**1.77(1.18-2.64)**
Density	1.33(0.78-2.25)	1.44(0.87-2.39)
Network Size	1.08(0.99-1.17)	1.07(0.99-1.15)
Network Characteristics		
Average Trust	0.76(0.56-1.03)	**0.74(0.56-0.97)**
Average Closeness	0.83(0.40-1.75)	0.67(0.41-1.10)

Models were adjusted age, education, duration of sex work, rural-urban residency, and the study site.
COR: Crude Odds Ratio; AOR: Adjusted Odds Ratio
*****Each variable was independently modeled to avoid potential multicollinearity. There were eight different models in this table.
^P-value for transitivity is 0.005, which is smaller than the Bonferroni corrected alpha level for 8 variables (alpha = 0.006). P-value for average trust is 0.029, which is not statistically significant with Bonferroni correction.

4.5 Appendix

Sensitivity Analysis 1:

Upon enrollment, we asked FSWs to report their sexual behaviors and the condom use in the past 24 hours. If they reported to have sexual behaviors, we collected the vaginal specimen for a prostate-specific antigen (PSA) test. The positivity of the PSA test indicated the absence of condom use during their last sexual activity and we could know whether they misreported their condom use status in their self-report questionnaire. The details of this design were described previously (109,110). Since over-report condom use and over-report HIV testing were both motivated by social desirability bias, FSWs who over-reported their condom use was presumably more likely to over-report their HIV testing status as well. Therefore, we ran a sensitivity analysis among the FSWs who correctly reported their condom use status to verify the robustness of the results;

A total of 562 FSWs who correctly reported their condom use status and HIV negative were included in the sensitivity analysis. Among the 572 FSWs, 64.5% (371) of them reported to be tested for HIV. This number is similar to the whole sample. Among FSWs who correctly reported their condom use verified by the PSA biomarker, prevalent syphilis infection, HIV knowledge, and partner's testing status maintained significant associations with HIV testing status (**Table 4-5**). Network Transitivity and network density were maintained significant associations HIV testing among FSWs with relatively large effect sizes (AOR=1.77; 95% CI: 0.76-4.13; AOR= 2.03; 95% CI: 0.96-4.31; respectively) and network trust was negatively associated with HIV testing in the subsample analysis as well (AOR=0.91; 95% CI: 0.53-1.57), although the results were not statistically significant (**Table 4-6**).

Sensitivity Analysis 2:

To address the potential confounding effects of types of social networks, we divided the perceived social support variable by the ego-alter relationships and examined whether the association between perceived social support and HIV testing uptake differed based on who was providing the support. We also run three additional models to verify if the association between network structural measurements and HIV testing behavior change depending on the amount of perceived social support.

As presented in **Table 4-7**, social support from family and friends were not associated with FSW's testing status and support from distant relatives, boyfriends and clients had negative impacts on it. The substantial effects of these social support were very small (Adjusted odds ratios are between 0.96 and 0.99). After adjusting for the amount of perceived social support, network transitivity and network size maintained significant associations with HIV testing status (AOR = 1.81; 95% CI: 1.09-2.97; AOR=1.21; 95% CI: 1.01-1.45; respectively).

Table 4-5:Multivariable Logistic Regressions Among "Honest" FSWs; N=562

Variables	Model 1	Model 2	Model 3
Individual Level			
Age	1.03(0.93-1.14)	1.01(0.92-1.11)	1.02(0.93-1.12)
Education			
Primary or Less	Reference	Reference	Reference
Middle School	1.03(0.59-1.78)	1.33(0.87-2.04)	1.23(0.76-2.03)
High School or above	1.74(0.39-7.83)	1.74(0.48-6.29)	1.55(0.43-5.65)
Marital Status			
Unmarried	Reference	Reference	Reference
Married	0.98(0.43-2.27)	0.70(0.30-1.60)	0.44(0.19-1.03)
Widowed/Divorced	0.67(0.31-1.46)	0.61(0.28-1.29)	0.57(0.26-1.24)
Residency: Migrant Vs. Local	0.93(0.46-1.86)	1.26(0.58-2.75)	1.24(0.59-2.60)
Duration of Sex Work	0.92(0.87-0.98)	0.96(0.87-1.05)	0.94(0.86-1.02)
Prevalent Syphilis	**1.96(1.18-3.24)**		
HIV knowledge	**1.53(1.33-1.76)**		
Meso Level			
Self-Reported Condom Use with Clients		1.02(0.95-1.09)	1.02(0.96-1.08)
Stable Partner's HIV Testing Status			
Never tested for HIV			Reference
Have tested for HIV			**8.94(3.43-23.32)**
Unknown			0.74(0.25-2.22)
No Partner			**0.39(0.23-0.68)**
City			
Qingdao	Reference	Reference	Reference
Nanning	**0.29(0.10-0.85)**	0.70(0.12-4.03)	**0.66(0.12-3.83)**
Hefei	**0.09(0.03-0.32)**	**0.12(0.03-0.58)**	**0.10(0.02-0.45)**

Table 4-6: Multivariable Logistic Regression Social Network Factors Among "Honest" FSWs

Variable	AOR (95%CI)
Network Function	
Total Support	1.00(0.99-1.01)
Network Structure	
Effect Size	0.89(0.76-1.03)
Constraint	1.59(0.72-3.52)
Transitivity	1.77(0.76-4.13)
Density	2.03(0.96-4.31)
Network Size	1.01(0.90-1.14)
Network Characteristics	
Average Trust	0.91(0.53-1.57)
Average Closeness	0.72(0.28-1.83)

Models were adjusted age, education, duration of sex work, rural-urban residency, and the study site.
AOR: Adjusted Odds Ratio

Table 4-7:Social Support by Different Sources

Network Function	Individual Models[1]	Model 1[2]	Model 2[2]	Model 3[2]
Total Support	1.00(0.99-1.01)	1.00(0.99-1.00)	1.00(0.99-1.00)	**0.99(0.97-1.00)**
Social Support				
Family	1.01(1.00-1.02)			
FSWs	1.00(0.98-1.01)			
Relatives	**0.99(0.98-1.00)**			
Boyfriends	**0.98(0.96-0.99)**			
Clients	**0.98(0.96-1.00)**			
Non-FSW Friends	1.00(0.99-1.01)			
Network Structure				
Transitivity	1.61(0.98-2.68)	**1.81(1.09-2.97)**		
Density	1.07(0.91-1.25)		1.59(0.91-2.80)	
Network Size	1.02(0.93-1.13)			**1.21(1.01-1.45)**

1. Models were adjusted for covariates, age, education, marital status, residency and duration of sex work.
2. Network Structures, adjusting by total amount of social support. We could observe that with the same level of perceived social support, network structures were still significant predictors for HIV testing behavior.

Chapter 5: Adjusting to Social Life in a Collectivistic Culture: The Wisdom of Female Sex Workers in China

Abstract

Background

Mid-age female sex workers (FSWs) are at elevated risk for HIV infection in China. Few studies have explored Chinese collectivism tendency in relation to social network characteristics and occupational stigma among mid-age female sex workers.

Methods

A total of 1245 FSWs (>35 years old) were recruited from Hefei, Nanning and Qingdao. Collectivistic tendency and occupational related stigma were used to predict the FSWs' social network characteristics. Linear regressions were used for statistical analysis. Interaction term (collectivism X stigma) was used to examine the potential interaction effects of these two variables on FSWs' social networks.

Results

Every one standard deviation (SD) increase in FSWs' collectivism tendency would lead to 0.18 SD decrease in social support (95% CI: -0.33, -0.04), 0.20 SD decrease in network effective size (95% CI: -0.30, -0.01), and 0.25 SD decrease in network betweenness (CI: -0.33, -0.09). Among the participants with the highest level of collectivistic tendency, the increase of occupational stigma would increase FSWs' network betweenness.

Conclusion:

FSWs who have the highest level of collectivistic tendency and perceived more social stigma related to their sex work are more willing to stay themselves at a "bridging" position and connect with weak social ties rather than a strong cohesive group. The

development of social network-based interventions to reduce HIV risk among FSW should take the complexity of culture into consideration.

5.1 Introduction

Extensive research has shown that an individual's social network has significant impact on ones' health behaviors, especially among marginalized populations, such as female sex workers (FSW), HIV positive individuals, and drug users (55,64,77). Positive influences and support from ones' social network peers could effectively reduce their engagement in HIV risk behaviors (63). Previous studies also suggest that female sex workers with a lower level of perceived social support (121,177,178), social engagement (82) and a high level of perceived intimacy with clients (77,177) are more likely to inconsistently use condoms with their clients (19). FSWs' personal social network is the primary source of their information support and social influence (179). Understanding FSWs' social networks is an important step in developing effective HIV behavioral intervention programs to reduce HIV risk behaviors among key populations, and ultimately to decrease HIV transmission rate in the general population.

The influence of Collectivism on Social Networks

Studying the influences of social networks on individual's behavior is especially useful in the Chinese culture. Chinese culture is predominantly collectivistic, with a strong emphasize on interdependence within the personal network and harmony within social groups (91). Different from individualistic culture, which is believed to be more self-reliant and self-interested, collectivistic culture promotes hierarchical relationships and values group interest over an individual's interest. Considering social relationships, individualistic people tend to form temporary relationships with dissimilar others, but collectivistic people tend to form permanent relationships with similar others (180). Collectivistic cultures are commonly believed to create strong and cohesive social groups

that, in theory, provide greater social support and social capital (62,181–183). However, the dynamic influence of collectivism on individual's social relationships is rather complicated. Although collectivistic culture emphasizes forming harmonic relationships between people and their personal network members, such as family members, friends or coworkers, this attempt may not always be successful. Empirical studies found that people from highly collectivistic countries receive a higher level of social resources but had a lower level of trust towards strangers and acquaintances (181,184). A recent study found that compared to Americans who are typically characterized as individualistic, Chinese individuals (typically characterized as collectivistic) show greater in-group vigilant towards their coworkers (93). Considering a within-China comparison, collectivistic rice farming population had higher level of in-group vigilance compared to their wheat farming individualistic counterparts (93). The historical difference between rice farming and wheat farming is that rice farming requires longer labor hours and more collaborations among famers while wheat farming operated with more independence. Sociologists believed that rice farming cultures are more collectivistic than wheat farming cultures, although this effect has been attenuated due to industrial shift and modernization (185). Overall, collectivistic Chinese culture puts additional pressure on social relationships.

Social Stigma and Personal Network

The cultural emphasis on interconnectedness can further amplify the perceptions of discrimination and stigma from individual's social networks, especially among vulnerable populations. Among people who live with HIV/AIDS (PLWHA) and men who have sex with men (MSM), individuals with higher level of collectivistic tendency

perceived higher level of social stigma (95,96). This social pressure can be manifested through individual's social networks. For example, in a longitudinal study about young black MSM in Chicago (YBMSM), participants are more likely to put themselves in a "bridging" position of their social networks after the positive HIV diagnosis. A "bridging" position is the position in a social network where a person's social contacts could only be connected through that person. This structural advantage can help YBMSM to selectively disclose their testing status without worry about being gossiped about because the information could not travel between YBMSM's social contacts by themselves (13).

Similar arguments could be made about female sex workers in China. Mid-age female sex (>35 years old) workers are especially vulnerable and considered as the bottom of the social hierarchy, opposed to their younger counterparts. Prostitution is illegal in China and the local law enforcement agencies practice campaign style policing, known as the "strike-hard" movements to periodically incarcerate FSWs (43,45,186). The Chinese government often portrays FSWs as "lazy", "materialism pursuit" and associates prostitution with political corruption (43). Even within the commercial sex industry, mid-age FSW are more likely to be paid less and experienced more stigmatization than younger FSWs (32,36,116).

This stigmatization combined with collectivistic cultural tendency creates an exceptionally antagonistic social environment for FSWs and may incentive them to plan their social networks accordingly. In this study, we utilize a multicenter egocentric social support network design to assess the influence of collectivistic tendency on individual social networks among mid-age female sex workers in China. Egocentric networks are a

special form of social networks that consist of one ego (female sex workers) and the egos' alters (ego's social network contacts who could provide social support to them). Using egocentric network design, we can effectively assess the functions, such as social support, social control and social influences, and the structures, such as the network size, density and shapes, of ego's personal network (48). Based on the above discussion, we hypothesize that 1) FSWs with a higher level of collectivistic tendency will perceive less social support; 2) FSWs with a higher level of collectivistic tendency and social stigma will have a lower level of trust towards their network members and more likely to put themselves in a "bridging" position in their personal network; 3) FSWs' social networks will be more affected by social stigma for those with a higher level of collectivistic tendency relative to those with a lower level of collectivistic tendency.

5.2 Method

Data source

Data was derived from a multicenter cross-sectional study in 2014. A total of 1245 eligible participants were female sex workers who were at least 35 years old, had exchanged sex for money at least once a week in the past month and lived in Hefei, Nanning or Qingdao for at least 3 months prior to the interview. Respondent Driven sampling (RDS) was used for recruitment. Demographic and social variables were collected through structured interviews using computer assisted personal interview (CAPI). Detailed data collection and recruitment protocols are described in previous publications (77,103,104).

Ethics Consideration

The study protocol was approved by the Institutional Review Board (IRB) of the University of Maryland, Shandong University School of Public Health and local regulatory agencies including Guangxi Center of Disease Control and Prevention, and Hefei Center of Disease Control and Prevention. Written informed consent was obtained for all the participants. Each eligible participant received interviews by trained interviewers using computer-assisted personal interviewing (CAPI) in a private room near the proximity to participants (less than 1 h-travel time). The identities of the study participants were protected, and no information collected in CAPI could be used to identify study participants. For taking part in this research study, FSWs were paid for their time and inconvenience in the amount of up to $18.5 ($9.5 for receiving an interview and $9 for introducing 3 friends to participate in this study). The research datasets were deidentified for data analysis and manuscript preparation.

Dependent Variables

Egocentric Social Support Networks

The Chinese Social Network Questionnaire (CSNQ) was used as the network inventory in this study (86,112). Name-generator was used to ask mid-age FSWs (egos) to list, by giving the pseudonyms, alters who would provide them social support. Each ego could name up to 30 alters. Alters could be friends, family members, relatives, pimps, venue owners, other FSWs, or other individuals whom the respondents knew for at least 1 month. Six items were used to define the egocentric network of an ego (166). Egos were asked to list alters who would: (1) lend them 200 Chinese dollars ($30 US); (2) take care of the them, if they were confined to bed for 2–3 weeks; (3) help or advise them if the they had problems regarding family or health issues, (4) agree with or support their ideas or actions; (5) make them feel respected or admired; or (6) convince them to confide in the alter. Each response was measured on a four-point Likert scale: (0) definitely will not provide, (1) probably will not provide, (2) probably will provide, (3) definitely will provide. The ego's social network was inclusive of all individuals who were perceived to provide at least one of the six types of social support to egos. Social and demographic information about the alters was collected from the egos, including the alters' age, education, marital status, and relation to the ego. No alter was interviewed in the data collection process.

Function of the Social Networks

Social Support: The above six-item measure for social support covers tangible support (items 1–3) and emotional support (items 4–6). The level of social support perceived by

each ego was the sum score of each social support item. The range of social support from each alter is 0 to 18. The observed range is 1-210.

Social Network Structures: Each ego was asked to identify whether each alter knew each other and generated a relational matrix according to their relationships. The types, strengths and direction of the alter-alter relationship were not measured as egos may not know such detailed information about their alters. Six network structural measurements were used in our study.

Network Size was the number of alters in an ego's network;

Network Density was the proportion of observed ties over the total possible ties in a network (ranged 0-1) (48). A network with a high density indicated the higher proportion of the interconnectedness between network members. This measurement has been widely used in the network literature (55,167,168).

Network Constraint of the ego was a Burt's structural hole index which measured the redundant ties around egos. It measures how much ego's alter are interconnected with other alters (164). An ego's network with less alters (i.e., ego would invest more on each alter) and more interconnected alters has a higher level of network constraint. An ego's network with more alters and less common connections among alters has a lower level of network constraint. Collectivistic society generally promotes small and intimate social relationships, which should be positively associated with network constraints. Therefore, we hypothesize that network constraint is positively associated with collectivistic tendency.

Effective Size was another Burt's structural hole index which measures the diversity of a social network. It referred to the number of non-redundant ties in a network. If an alter

was completely disconnected with other alters in an egocentric network, this ego-alter tie was considered nonredundant. Nonredundant ties in a support network could provide unique and independently acquired resources to the ego. However, more nonredundant ties in a social network usually suggested a lower level of social cohesion. Effective size was calculated as the number of alters minus the average ties of alters within the ego network, not counting ties to ego (164,170). Network effective size is the opposite measurements of network constraint.

Ego betweenness measured the "bridging potential" of ego within ego's personal network. It was the summation of the number of shortest paths from every two alters through ego. For example, if alter A and alter B are connected on their own, the shortest path for A and B to connect will not go through ego. Hence, ego was not at the bridging position between A and B (88). Ego betweenness is a proxy to estimate the FSWs' "social power". FSWs who have higher betweenness centrality have more information control over their social networks.

Network Characteristics

Average alter trust: Egos were asked to rate the level of trustiness to each alter on a 5-point Likert scale: (0) Do not trust at all; (1) Do not trust; (2) Do not care; (3) Trust; (4) Very trustworthy. The average alter trust is the average rating of all the alters in ego's network.

Main Independent Variables

Occupational stigma was measured based on an eight-item measurement scale that was constructed to assess the respondents' perceptions of stigmatizing attitudes and/or discrimination towards sex workers. Participant responses were ranked on a four-point

scale ranging from (0) 'strongly disagree' to (3) 'strongly agree.' Scores were summed (range 0–24) with higher scores indicating greater perceived stigma. This measurement was validated in our previous publication (114). The Cronbach's alpha was 0.86 (115). The 8-item inventory used to measure it could be found in the **Appendix**.

Collectivism: The Individualism–Collectivism Interpersonal Assessment Inventory (ICIAI) was used to assess the tendencies of individualism and collectivism. ICIAI provides a measure of the tendency toward individualism or collectivism and the perception of IC values with interpersonal orientation in friendship relationships (92). The 15-item inventory used to measure it could be found in the **Appendix.**

Statistical Methods

Linear regression models were used to assess the associations between collectivism and each social network outcome variable including total support, average network trust, ego constraint, effective size, ego betweenness, density and network size. We additionally adjusted for variables that may influence the individual's social networks, including FSW's age, duration of sex work, education level, marital status, urban-rural residency and study sites. Similarly, we ran the same model using occupational stigma instead of collectivism as our primary independent predictor. To account for multiple comparison bias in this study, Bonferroni corrected alpha value should be 0.007 to be considered as statistically significant. Confidence interval was retained at 0.05 level for easy interpretation.

Next, to assess the potential interaction effects of collectivism and occupational stigma on FSWs' social networks, we fitted the linear regression models included collectivism, occupational stigma and their interaction term on each outcome variable and

adjusting for the above-mentioned potential confounding variables. An interaction term (i.e., occupational stigma*collectivism) was created and entered into the model. Effect plots and coefficient were used to visualize the models with significant interaction effects.

Since there was no natural unit for social network measurements, collectivism, and network stigma, we standardized these continuous variables to convert them to the same scale and to improve the interpretability of these variables. All the continuous variables including the aforementioned variables, age and duration of sex work were subtracted by their own mean and divided by one standard deviation. The coefficients in the regression analysis should be interpreted as: the change of standard deviation in each dependent variable corresponding to the change of one standard deviation of the independent variables. Original scales were kept in the descriptive tables.

There was no missing value in the study. However, since network measurements were not meaningful when FSWs had no social contact, we excluded the three FSWs with no social contacts in their support network. RDS sampling weights were adjusted in this study to account for the nonrandom sampling strategy. RDS sampling weights were estimated using RDS analyst, RDS-II method (110). Egocentric network measurements were calculated using R package igraph.

5.3 Results

Table 5-1 presents the study participant's demographic characteristics. A total of 1245 female sex workers who were 35 years old and above were recruited in our study (418 in Nanning, 407 in Hefei and 420 in Qingdao). The average age for the study participants was 40 years old (standard deviation (SD) =5.44). 43% (547) of the

participants had less than middle school education and only 10% (122) of them received high school and above education. 69% (865) of them were migrant workers from rural area. 49% (610) of the participants were married, 41% (520) of them were divorced or widowed, and 9% (116) were never married. On average, each ego had 4.67 social contacts in their personal networks (range: 0-21).

Across the three cities, FSWs from Qingdao had worked in commercial sex industry for a longer time. The average length of working as sex workers in Qingdao was 6.46 years and the number, notably higher than Hefei, 2.11 years and Nanning, 3.76 years. FSWs from Nanning had similar collectivism tendency as FSWs from Qingdao (30.23 and 29.07, respectively), and FSWs from Hefei had the lowest collectivistic tendency (24.54) among the three cities.

In regression analyses (Error! Reference source not found.), after adjusting for age, education, marital status, duration of sex work, urban-rural residency and study sites, one standard deviation increase in an ego's collectivistic level would lead to 0.18 standard deviation (95% CI: -0.33, -0.04) decrease in the ego's perceived social support, 0.20 standard deviation (95% CI: -0.30, -0.01) decrease in the ego's effective size, 0.21 standard deviation (95% CI:) decrease in the ego's network betweenness, and -0.25 standard deviation (95% CI: -0.39, -0.12) decrease in the ego's network size. At the same time, one standard deviation increase in an ego's collectivistic level would lead to 0.09 standard deviation (95% CI: 0.01-0.17) increase in the ego's trust towards her network members, and 0.16 standard deviation (95% CI: 0.05, 0.26) increase in the ego's network constraint. After Bonferroni correction for multiple comparisons, the effects on network

constraint, effective size, network betweenness, and network size remained statistically significant.

One standard deviation increase in an ego's perceived sex work related stigma would lead to 0.83 standard deviation (95% CI: -0.14, -0.02) decrease in the ego's perceived social stigma). This association was still marginally significant ($p < 0.1$) with Bonferroni correction. Other network characteristics were not significantly associated with occupational stigma. The association and the magnitudes of the effects were consistent between bivariate models and adjusted models.

We further examined the potential interaction of collectivism on the association between occupational stigma and social network measurements. As shown in Error! Reference source not found., , the interaction term of collectivism and occupational stigma was significant for social network trust model and ego betweenness model. Collectivism tendency was positively associated average trust toward network members if the ego perceived above average social stigma related to their sex work (Error! Reference source not found.**)**. When FSWs perceived higher level of social stigma, collectivism, the positive influence of collectivism on network trust became stronger. On the contrary, when FSWs perceived higher level of social stigma, collectivism, the negative association between collectivism and network betweenness was attenuated. When FSWs perceived very high levels of social stigma, the marginal effect of collectivism on network betweenness became positive, although the coefficients were not statistically significant (**Figure 5-2**).

5.4 Discussion

This study had three main findings. First, Chinese female sex workers who had a high level of collectivistic tendency were more likely to have smaller but more intimate social relationships. Inevitably, they also perceived less social support in general. Second, occupational stigma significantly decreased FSWs' social support and their network trust but did not have significant influence on the structures of FSWs' social networks. Third, the effect of FSWs' occupational stigma on social network structures was modified by their collectivism tendency. For FSWs with a lower level of collectivistic tendency, FSWs who perceived a higher level of social stigma were more likely to be a cohesive social group. However, for FSWs with a higher level of collectivistic tendency, this associated was reversed. FSWs who perceived higher level social stigma would have more bridging potential in their network.

Consistent with previous studies (96,187,188), social support and average network trust were negatively associated with occupational stigma. Evidence from previous path analytic studies found that social stigma may mediate the effects between individual's collectivism and perceived social support among PLWHA and MSMs (95,96). Therefore, we also fitted the mediation models but found no mediation effects of occupational stigma between collectivism and the above two social network measurements. In facts, there was no significant association between occupational stigma and network support independent from collectivism. The differences between the current study and the previous two studies may be due to (1) different measures of collectivism (the collectivism tendency was measured in the context of three social groups, family members, friends, and neighbors in the PLWHA study, but only friend group was

included in the measure in the current study, and Triandis' measurement was used in the MSM study); (2) different study populations (PLWHA, MSM, and FSWs) that may share different mechanisms for social support, stigma, and networking, (3) different types of stigma (HIV-related stigma, homosexuality-related stigma, and sex work related stigma), and (4) different sources of social support received by different types of study populations (e.g., family members or friends who inject drugs together). The main sources of FSWs' social support were family members and their FSW friends, only 15% of the social support came from FSWs' non-FSW friends. Other studies indicate that social support from FSW friends and family is typically less stigmatizing compared to social support from sexual partners or neighbors (95,96). To verify the assumption, we further examined the correlation between occupational stigma and different sources of social support (**Appendix**). Occupational stigma was negatively associated with support from FSW peers, sexual partners and their gatekeepers (e.g. pimps, managers, and other senior FSWs) but not associated with non-FSW friends, family members or relatives. One possible explanation was that FSWs who experienced a higher level of social stigma related to their work would actively disassociate themselves from their "sex worker life". It was also more difficult for them to keep close relationships with their other connection because of the feeling of shame, which would also explain the negative association between occupational stigma and average network trust.

This result of this study raises interesting questions about best strategies for conducting network-level interventions. Many researchers suggest that network-level intervention are effective because stigmatized populations are more willing to seek help from similar people who shared the same social stigmatization (189). Empirical studies

have documented social stigma as a barrier for health seeking behaviors among FSWs because the fear of stigma in front of healthcare professionals (69). For FSWs, peer FSW friends and gatekeepers are important sources of health related information (70,190). Participation in FSW groups is recognized as a facilitator of consistent condom use with clients and HIV health seeking behaviors (19,82). However, if FSWs internalize the stigma related to their sex work, they might be less willingly to accept help from their peer FSWs. Therefore, reducing the social stigma related to sex work are important in delivering effective intervention strategy. Anonymous intervention, such as vending-machine based urine collection kits for HIV testing, may work better among highly stigmatized individuals (191).

The negative association between FSWs' collectivistic tendency on their social network variables confirmed the previous intuition that collectivistic cultures endorse smaller but more intimate social relationships (91,180). FSWs with higher level of collectivistic tendency tended to have smaller and more close-knitted social networks. One of our assumption was that because of the collectivistic tendency and social stigma, FSWs would prefer to be in a "bridging position" to cope with the potential discrimination and secure their social relationships by controlling the information flow within their networks. We partly observed this phenomenon. Collectivistic tendency was positively associated with network constraint, the measurement of small and cohesive network, but negatively associated with network effective size, the measurements of large and sparser network, and ego betweenness, the measurement of network bridging potential. In the model with the interaction term, we found that FSWs with high collectivistic tendency would increase their network betweenness as they perceived more

social stigma. The possible reason for this finding is that individual's social relationships were relatively stable, especially among family and friends in a collectivistic culture. Therefore, social stigma might influence the FSWs' perception of the social networks, such as the trust towards their network members, but not the social relations. However, when the social pressure was further intensified, FSWs would be forced to change their social networks. According to previous studies (95,96) and our data, collectivistic tendency significantly increased individual's perception of social stigma. Therefore, when FSWs' collectivistic tendency and social stigma were both high, FSWs were forced to make change and increase their control of information over their personal social networks. Unfortunately, since we only have cross-sectional data on FSWs' psychological characteristics, we could not observe the change on FSWs' social networks. Longitudinal data is needed to further investigate the impact of these larger societal factors on FSWs' social networks.

The main advantage of this study was that it examined a unique perspective of the influence of culture and social stigma on the social networks of a highly marginalized population. In addition to the traditional network measurements, such as social support, network size and network trust, we utilized some novel structural measurements to further understand the process of social capital. The multicenter study design also gave us the advantage of studying with-in culture heterogeneity. Besides the individual level measurements of collectivism, the three different cities also differed significantly on their level of collectivism. Based on the rice theory, Nanning, Hefei and Qingdao conveniently located at rice farming, mixed and wheat-farming regions and presumably had high, medium and low level of collectivistic tendency respectively (185). We had a relatively

large variation of individual's level of collectivism compared to other single-centered study. This variation could also serve as a proxy as collectivism measurements. As depicted in Table 5-3, the association between study sites and network measurements was at the same direction as the individual-level measurements. There were several limitations to this study. First, because of the limitations of the questionnaire, only individual's collectivistic tendency towards friends were collected. Second, FSW's egocentric social networks were only collected through FSWs' themselves. No alter was interviewed during the data collection. The network structural measurements were calculated regardless of the strength of the relations. Information bias might exist due to social desirability. Third, this finding was only based on a cross-sectional study design, no causal inference could be drawn from the data. Forth, recall bias may take place as FSWs may not accurately report the size of network. FSWs may underreport their perceived stigma due to social desirability bias. Although respondent-driven sampling method is considered as one of the best strategies to recruit marginalized populations, the recruited sample is still intercorrelated, which can inflate the Type I error rate.

5.5 Conclusion

This study provides much needed data on how Chinese collectivistic culture interacts with social stigma and how these factors jointly influence the social networks of FSWs' in China. These findings contributed to our knowledge by providing a possible explanation of how these cultural and societal factors influenced the FSW's choice to optimize their social networks.

Table 5-1: Descriptive Analysis for Egos

	Nanning N=418	Hefei N=407	Qingdao N=420	Total N=1245
Continues Variables	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Age(years)	38.25(3.74)	39.53(5.07)	42.41(6.32)	40.07(5.44)
Duration of sex work (years)	3.76(2.75)	2.11(2.19)	6.46(3.90)	4.13(3.53)
Collectivism	30.23(8.56)	24.54(7.65)	29.07(7.36)	27.98(8.24)
Occupational Stigma	15.58(1.88)	16.78(3.31)	16.84(3.07)	16.39(2.88)
Network Characteristics				
Function of Social Network				
Total Support	67.52(35.51)	50.96(26.03)	39.86(21.90)	52.78(30.60)
Structure of Social Network				
Effect Size	3.50(1.97)	2.74(1.73)	2.20(1.30)	2.81(1.77)
Constraint	0.49(0.23)	0.56(0.27)	0.61(0.26)	0.55(0.26)
Ego betweenness	15.64(17.35)	9.54(13.35)	5.08(7.54)	10.08(14.03)
Density	0.48(0.30)	0.50(0.37)	0.55(0.35)	0.51(0.34)
Network Size	5.69(2.58)	4.50(2.30)	3.84(1.69)	4.67(1.77)
Network Characteristics				
Average Network Trust	3.03(0.47)	2.96(0.64)	2.90(0.65)	2.96(0.60)
Categorical Variables	*N (%)*	*N (%)*	*N (%)*	*N (%)*
Education				
Primary or Less	151(36%)	202(50%)	193(46%)	547(43%)
Middle School	213(51%)	171(42%)	193(46%)	577(47%)
High School	54(13%)	34(8%)	34(8%)	122(10%)
Marital Status				
Unmarried	52(12%)	47(12%)	17(4%)	116(9%)
Married	237(57%)	226(56%)	147(35%)	610(49%)
Divorced or Widowed	129(31%)	134(33%)	256(61%)	520(41%)
Residency				
Urban	103(25%)	162(40%)	115(27%)	380(31%)
Rural	315(75%)	245(60%)	305(73%)	865(69%)

Table 5-2: Linear Regression Analysis

Standardized Dependent Variables	Collectivism (Standardized) Bivariate β (95% CI)	Adjusted β* (95% CI)	Adjusted P-value
Total Support	-0.15 (-0.25, -0.04)	-0.18 (-0.33, -0.04)	0.01
Average Trust	0.07 (0.00, 0.14)	0.09 (0.01, 0.17)	0.03
Ego Constraint^	**0.14 (0.05, 0.22)**	**0.16 (0.05, 0.26)**	**0.01**
Effective Size^	**-0.16 (-0.24, -0.09)**	**-0.20 (-0.30, -0.01)**	**0.00**
Ego betweenness^	**-0.18 (-0.27, -0.09)**	**-0.21 (-0.33, -0.09)**	**0.00**
Density	0.05 (-0.02, 0.11)	0.06 (-0.01, 0.23)	0.07
Network Size^	**-0.21 (-0.33, -0.09)**	**-0.25 (-0.39, -0.12)**	**0.00**
Occupational Stigma (Standardized)			
Total Support	**-0.13 (-0.21, -0.05)**	**-0.83 (-0.14, -0.02)**	**0.01**
Average Trust	-0.04 (-0.23, -0.05)	-0.03 (-0.11, 0.05)	0.37
Ego Constraint	0.05 (-0.05, 0.15)	0.02 (-0.07, 0.10)	0.69
Effective Size	-0.09 (-0.19, 0.22)	-0.05 (-0.13, 0.04)	0.24
Ego betweenness	-0.06 (-0.15, 0.03)	-0.03 (-0.10, 0.03)	0.29
Density	0.01 (-0.11, 0.12)	-0.01 (-0.12, 0.10)	0.80
Network Size	-0.10 (-0.20, 0.01)	-0.05 (-0.13, 0.02)	0.13

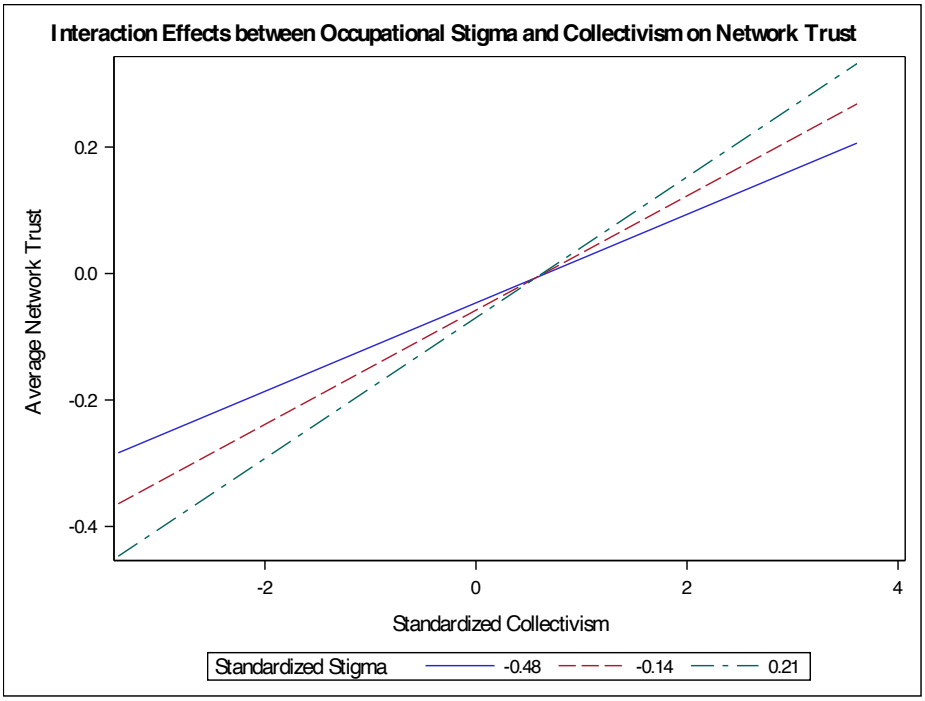
All dependent variables were separately estimated. Both dependent variables and primary independent variables were standardized in model fitting.
*Models were adjusted for age, education, marital status, duration of sex work, urban-rural migrant status and study sites.
^Variables were still significant at Bonferroni corrected alpha level= 0.007.

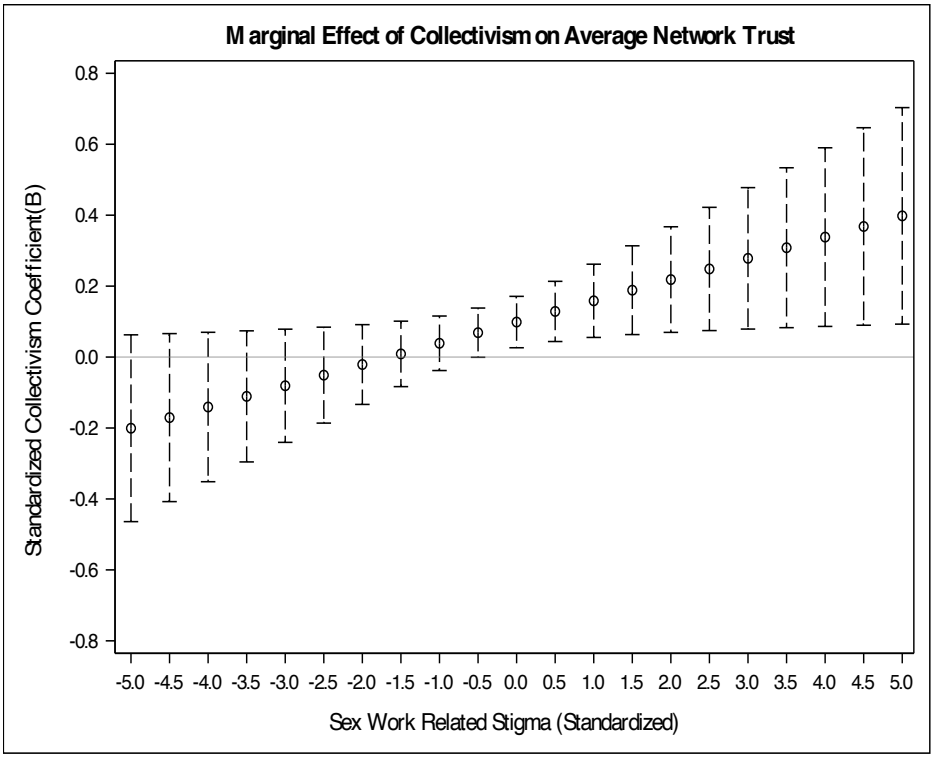
Table 5-2: Linear regression Analysis with Interaction Effects

Dependent Variables	Total Support (95% CI)	Average Trust (95% CI)	Ego Constraint (95% CI)	Effective Size (95% CI)	Ego Betweenness (95% CI)
Age	-0.01	0.01	0.08	-0.08	-0.03
(Standardized)	(-0.03,0.01)	(-0.01, 0.02)	(0.00, 0.017)	(-0.17, 0.00)	(-0.09. 0.03)
Duration of sex work	0.04	0.02	-0.06	0.06	0.02
(Standardized)	(0.00, 0.07)	(0.00, 0.04)	(-0.15, 0.17)	(-0.05, 0.016)	(-0.06,0.10)
Education					
Primary or Less			Reference		
Middle School	0.28	0.07	-0.24	-0.20	-0.15
	(0.15, 0.40)	(-0.17, 0.32)	(-0.40, -0.07)	(-0.04, 0.37)	(-0.01, 0.31)
>High School	0.29	0.06	-0.27	0.23	0.07
	(0.08, 0.49)	(-0.15, 0.28)	(-0.51, -0.02)	(0.00, 0.46)	(-0.09, 0.22)
Residency					
Local Urban			Reference		
Migrant Rural	0.10	0.14	0.02	-0.03	-0.07
	(-0.05, 0.24)	(-0.10, 0.38)	(-0.21, 0.24)	(-0.22, 0.16)	(-0.23, -0.08)
Marital Status					
Unmarried			Reference		
Married	0.14	0.05	0.03	0.04	0.08
	(-0.05, 0.32)	(-0.27, 0.37)	(-0.27, 0.32)	(-0.20, 0.28)	(-0.16, 0.31)
Widowed/Divorced	0.10	0.13	0.11	0.05	0.11
	(-0.08. 0.29)	(-0.26, 0.52)	(-0.14, 0.35)	(-0.21, 0.31)	(-0.14, 0.36)
City					
Nanning			Reference		
Hefei	-0.52	0.06	0.30	-0.48	-0.50
	(-0.81, -0.24)	(-0.23, 0.35)	(0.02, 0.58)	(-0.82, -0.14)	(-0.85, -0.14)
Qingdao	-0.85	-0.21	0.46	-0.65	-0.69
	(-1.26, -0.44)	(-0.75, 0.34)	(0.17, 0.75)	(-1.01, -0.30)	(-1.04, -0.34)
Sociocultural Factors					
Collectivism	-0.39	0.10	0.16	-0.20	-0.21
(Standardized)	(-0.78, -0.01)	(0.03, 0.17)	(0.05, 0.27)	(-0.29, -0.11)	(-0.33, -0.10)
Stigma	-0.18	-0.03	-0.01	0.00	-0.02
(Standardized)	(-0.31, 0.04)	(-0.11, 0.04)	(-0.09, -0.06)	(-0.06, 0.06)	(-0.03, 0.07)
Interaction Term[1]	0.27	**0.06**	-0.02	0.07	**0.08**
	(-0.07, 0.60)	**(0.00, 0.12)**	(-0.11, 0.07)	(-0.02, 0.15)	**(0.02, 0.14)**

1. The interaction term is the product of standardized collectivism and standardized social stigma.

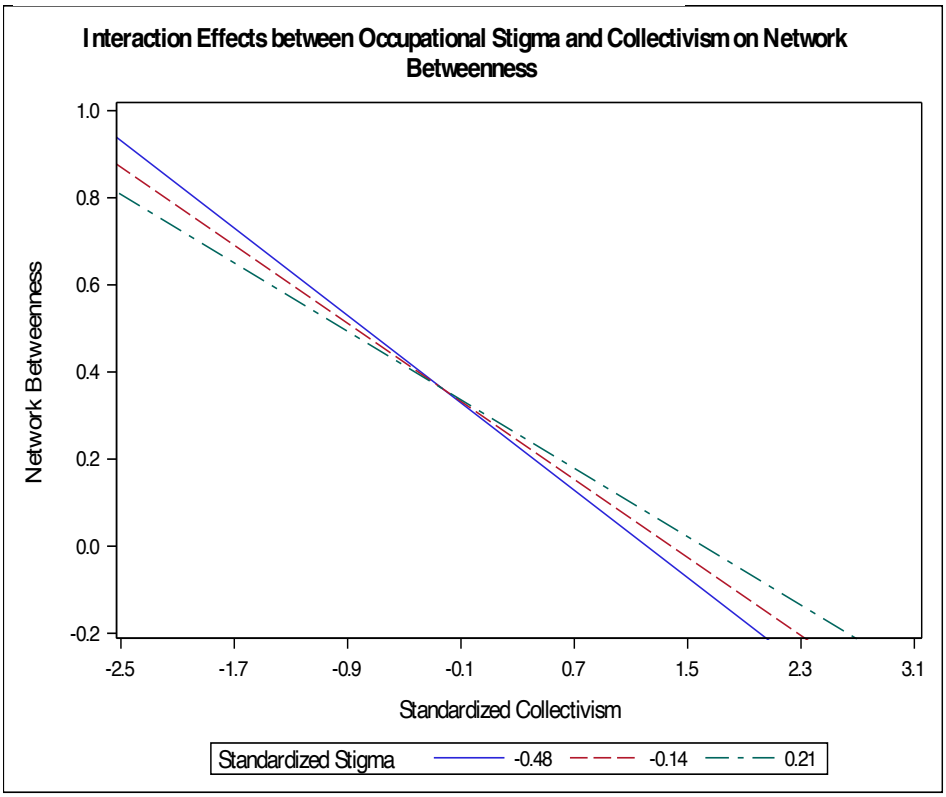
Figure 5-1: Effects of Collectivism on Average Network Trust

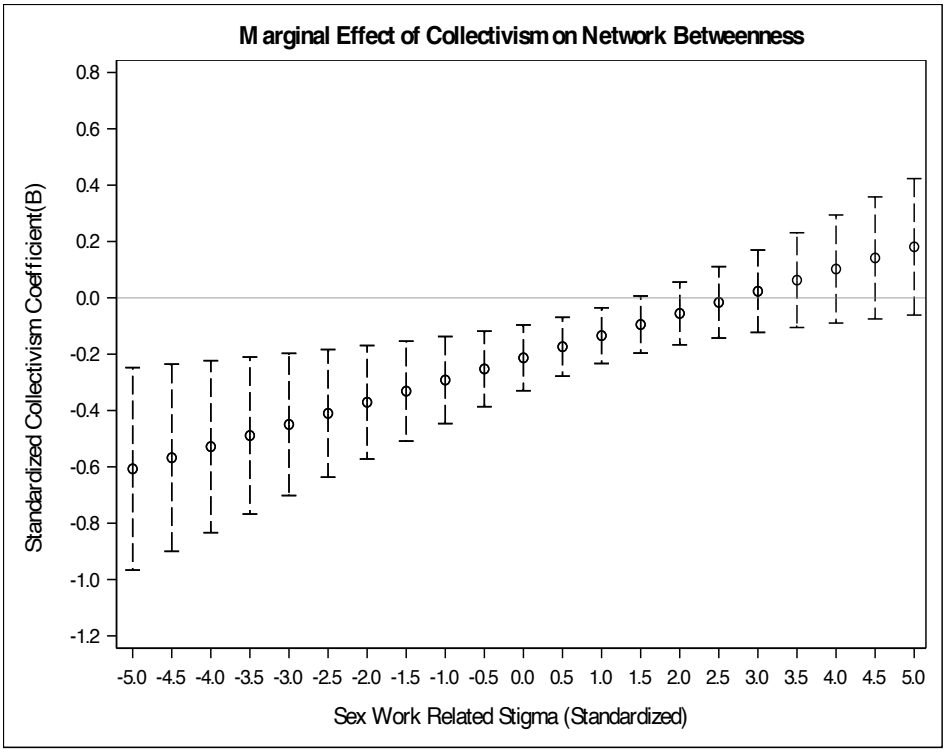




Standardized collectivism level was sliced based on 25%, 50% and 75 % quantiles.

Figure 5-2: Effects of Collectivism on Network Betweenness





Appendix

Occupational Stigma Measurements:

Participant responses were ranked on a four-point scale ranging from (0) ‘strongly disagree’ to (3) ‘strongly agree.’ Scores were summed with a range of 0–24. The questions used to ask occupational stigma are:

Do you agree with the following statements about mid-age female sex workers(miss)?

Table 5-4: 8-item Scale to Assess FSWs' Occupational Stigma

1.My none-FSW friends would stop being friends with me if they knew my job.
2. People around me (colleagues or neighbors) would rebel me if they knew my job.
3. My none-FSW friends would look down to me if they knew my job.
4. People around me (colleagues or neighbors) would look down my family me if they knew my job.
5. My family would “lose face” if they knew my job.
6. My family’s reputation would be compromised if they knew my job.
7. My husband or boyfriend would leave me if he knew my job.
8. My children would be ashamed of me if they knew my job.

Collectivism Measurements:

In order to maintain a good friendship with your friends, which of the following items is most important to keep a good relationship? (0 not at all important; 1 somehow important; 2 important; 3 very important; 4 extremely important).

Table 5-5: 15-Item Scale used to Assess Collectivism towards Friends (113)

1. Maintain self-control toward them
2. Share credit for their accomplishments.
3. Share blame for their failures.
4. Respect and honor their traditions and customs.
5. Be loyal to them
6. Sacrifice your possessions for them
7. Respect them
8. Maintain harmonious relationships with them.
9. Nurture or help them.
10. Maintain harmonious relationships with them. _
11. Maintain a stable environment (e.g., maintain the status quo) with them.
12. Cooperate with them.
13. Communicate verbally with them.
14. "Save face" for them.
15. Follow norms established by them.

Table 5-6: Linear Regressions using Occupational Stigma to predict Social Support by different Sources

Source of Social Support	Occupational Stigma
FSW friends	-0.04(-0.10, 0.02)
Family Members	0.01 (-0.10, 0.12)
Clients	-0.10 (-0.26, 0.05)
Boyfriends*	-0.07 (-0.12, -0.02)
non-FSW Friends	0.04 (-0.04, 0.11)
Gatekeepers*	-0.08 (-0.16, -0.01)
Relatives	-0.01 (-0.06, 0.04)

Age, duration of sex work, education, rural-urban residency, marital status and study site were adjusted in the model fittings

*P value was not significant at Bonferroni corrected alpha level (0.007).

Chapter 6: Conclusion

Social networks have proven to be a useful tool in understanding disease spread and human behaviors. The idea of a social network forces people to look beyond the problems at an individual level and connecting individuals with the bigger world. The resources, connections, and opportunities embedded in people's social network determine their chances of success. An 18-year old black schoolgirl from South Africa is at higher risk of HIV infection than a 40-year old female sex worker in from China simply because she is more likely to meet with a HIV positive man. For vulnerable populations who cannot access public resources easily, social networks become their only source of support and influence. Social networks determine their health and well-beings.

Although social network research in HIV/AIDS is much needed, the challenges in designing appropriate social network studies among vulnerable populations cannot be easily resolved. Our systematic review found that traditional sampling strategies, interview processes, and ethnographical work cannot effectively identify the whole network. The level of precision that the data is required to model social networks cannot be met by these questionnaire data alone. It is almost impossible to interview the sexual partners of FSWs because of the heterogeneity of this population. Unlike MSM or IDU networks, which are predominantly comprised of a behavioral homogenous population, the clients of FSWs are made up of a complex combination of other high-risk populations, such as IDUs, migrant workers, men who visit prostitutes at regular basis, etc., and the general populations, such as men who visit prostitute occasionally or socially. According to the National Survey of Sexual Attitudes and Lifestyles, a probability sample survey of the British population, 11% of the male participants

reported to ever having paid for sex by female sex workers in their lifetime, and they did not count FSWs as their sexual partners when they reported their number of lifetime sexual partners (192). These male clients and their associated are almost impossible to observe in research settings.

In addition to the potential HIV transmission ties, social influence is another important aspect of social networks. In 19th century, Emile Durkheim observed that although the population of Paris renewed itself rapidly, the suicide rates in Paris remained constant over the years (193). Individual's health choice is not only determined by their own choice, but also heavily influenced by the existing social structural and relational characteristics around them. Using social network methods, we could explore the potential mechanism of how social networks might influence a person's health choice. In most of the previous literature, social support is believed to be beneficial for an individual's health outcome. However, in manuscript 2, we found that the amount of social support was not associated with the uptake of HIV testing behavior among Chinese FSWs. A large and cohesive social network was the key to behavioral change among FSWs. Social support could provide tangible resources for an individual to help them be in better health. For example, if an FSW needs to visit a doctor, a social support contact may drive her to the clinic. Unfortunately, these types of help may not be sufficient to facilitate behavioral change. Positive reinforcements, positive social norms and stable social environment are essential to improve a FSWs' self-esteem, social competence and self-efficacy, and eventually will lead to positive behavioral changes. This finding provide additional empirical evidence on how social networks might change individual's health behaviors.

Social network is a reciprocal process. In order to receive social support or be a part of the social norms, individuals need to provide similar support to their social contacts. Therefore, although a large and cohesive social network may provide substantial benefits for FSWs, their ability to maintain a social network may be limited to their resources and cultural beliefs. Chinese culture is known to be in favor of smaller and cohesive social groups, which could limit FSWs willingness to secure a large social network. In manuscript 3, we found that Chinese mid-age FSWs who had higher levels of collectivistic tendency were more likely to have smaller social networks, received less social support and were more likely to have a denser network. However, this preference of denser social network may not be ideal for highly stigmatized FSWs. The influence of collectivism on FSWs' social networks was attenuated by their perceived level of social stigma. If collectivistic FSWs perceived high level of social stigma related to their sex work, they were more likely to maintain a sparser network which they had more control over it.

This dissertation added to the current literature on the association between social networks and HIV among FSWs by providing a review on its method applications and provided interesting empirical evidence on how social networks may influence FSWs' HIV preventive behaviors and the root of the social network.

Bibliography

1. World Health Organization. Number of people (all ages) living with HIV [Internet]. Geneva, Switzerland: WHO. 2018. Available from: https://www.who.int/gho/hiv/epidemic_status/cases_all/en/

2. Yang S, Keller FB, Zheng L. Social network analysis: methods and examples. Sage Publications; 2016.

3. Milgram S. The small world problem. Psychol Today. 1967;2(1):60–7.

4. Winkelstein W, Wiley JA, Padian NS, Samuel M, Shiboski S, Ascher MS, et al. The San Francisco Men's Health Study: Continued decline in HIV seroconversion rates among homosexual/bisexual men. Am J Public Health. 1988/11/01. 1988;78(11):1472–4.

5. Winkelstein W, Samuel M, Padian NS, Wiley JA, Lang W, Anderson RE, et al. The San Francisco Men's Health Study: III. Reduction in human immunodeficiency virus transmission among homosexual/bisexual men, 1982-86. Am J Public Health [Internet]. 1987/06/01. 1987;77(6):685–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/3646848

6. Rhodes T, Singer M, Bourgois P, Friedman SR, Strathdee SA. The social structural production of HIV risk among injecting drug users. Soc Sci Med. 2005;61(5):1026–44.

7. Mcleroy KR, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. Heal Educ Behav. 1988;15(4):351–77.

8. Dandona R, Dandona L, Gutierrez JP, Kumar AG, McPherson S, Samuels F, et al. High risk of HIV in non-brothel based female sex workers in India. BMC Public Health. 2005;5(1):87.

9. Evans C, Lambert H. The limits of behaviour change theory: Condom use and contexts of HIV risk in the Kolkata sex industry. Cult Heal Sex. 2008;10(1):27–41.

10. Cohen DA, Scribner RA, Farley TA. A structural model of health behavior: A pragmatic approach to explain and influence health behaviors at the population level. Prev Med (Baltim). 2000;30(2):146–54.

11. Schneider J, Cornwell B, Jonas A, Lancki N, Behler R, Skaathun B, et al. Network dynamics of HIV risk and prevention in a population-based cohort of young Black men who have sex with men. Netw Sci. 2017;5(3):381–409.

12. Young LE, Fujimoto K, Schneider JA. HIV Prevention and Sex Behaviors as Organizing Mechanisms in a Facebook Group Affiliation Network Among Young Black Men Who Have Sex with Men. AIDS Behav. 2018 Oct;22(10):3324–34.

13. McFadden RB, Bouris AM, Voisin DR, Glick NR, Schneider JA. Dynamic social support networks of younger black men who have sex with men with new HIV infection. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2014;26(10):1275–82.

14. Shah NS, Iveniuk J, Muth SQ, Michaels S, Jose JA, Laumann EO, et al. Structural bridging network position is associated with HIV status in a Younger Black men who have sex with men epidemic. AIDS Behav. 2014;18(2):335–45.

15. Amirkhanian YA. Social networks, sexual networks and HIV risk in men who have sex

with men. Vol. 11, Current HIV/AIDS Reports. 2014. p. 81–92.

16. Qiao S, Li X, Stanton B. Social support and HIV-related risk behaviors: A systematic review of the global literature. Vol. 18, AIDS and Behavior. 2014. p. 419–41.

17. Qiao S, Li X, Zhang C, Zhou Y, Shen Z, Tang Z, et al. Psychological fears among low-paid female sex workers in southwest China and their implications for HIV prevention. PLoS One. 2014;9(10).

18. Perkins JM, Subramanian S V., Christakis NA. Social networks and health: A systematic review of sociocentric network studies in low- and middle-income countries. Soc Sci Med. 2015;125:60–78.

19. Shushtari ZJ, Hosseini SA, Sajjadi H, Salimi Y, Latkin C, Snijders TAB. Social network and HIV risk behaviors in female sex workers: A systematic review. BMC Public Health. 2018;18(1):1020 %! Social network and HIV risk behaviors in f.

20. Shelton RC, Lee M, Brotzman LE, Crookes DM, Jandorf L, Erwin D, et al. Use of social network analysis in the development, dissemination, implementation, and sustainability of health behavior interventions for adults: A systematic review. Vol. 220, Social Science and Medicine. 2019. p. 81–101.

21. Wang K, Brown K, Shen SY, Tucker J. Social network-based interventions to promote condom use: A systematic review. Vol. 15, AIDS and Behavior. 2011. p. 1298–308.

22. National Center for AIDS/STD Control and Prevention CC. 国家卫生健康委员会2018年11月23日例行新闻发布会散发材料之一：我国艾滋病防治工作进展. 11/23. 2018.

23. National Center for AIDS/STD Control and Prevention CC. 全国初步完成艾滋病异性传播危险因素快速评估工作 [Internet]. 12/29. 2014. Available from: http://www.chinaaids.cn/yqjc/hdjz2/201412/t20141229_108527.htm

24. Zhu TF, Wang CH, Lin P, He N. High risk populations and HIV-1 infection in China. Vol. 15, Cell Research. 2005. p. 852–7.

25. China Statistics Bureau. China statistical yearbook. Chinese Stat Bur. 2012;

26. Klasen S, Wink C. Tournant décisif du sexisme en matière de mortalité? Le point sur le nombre de femmes disparues. Popul Dev Rev. 2002;28(2):285–312.

27. Bongaarts J, Guilmoto CZ. How Many More Missing Women? Excess Female Mortality and Prenatal Sex Selection, 1970-2050. Popul Dev Rev. 2015;41(2):241–69.

28. Liu H, Li S, Feldman MW. Forced bachelors, migration and HIV transmission risk in the context of China's gender imbalance: A meta-analysis. Vol. 24, AIDS Care - Psychological and Socio-Medical Aspects of AIDS/HIV. 2012. p. 1487–95.

29. South SJ, Trent K. Imbalanced sex ratios, men's sexual behavior, and risk of sexually transmitted infection in china. J Health Soc Behav. 2010;51(4):376–90.

30. Tucker JD, Henderson GE, Wang TF, Huang YY, Parish W, Pan SM, et al. Surplus men, sex work, and the spread of HIV in China. Vol. 19, Aids. 2005. p. 539–47.

31. Chen XS, Liang GJ, Wang QQ, Yin YP, Jiang N, Zhou YJ, et al. HIV prevalence varies between female sex workers from different types of venues in southern China. Sex Transm Dis. 2012;39(11):868–70.

32. Chen XS, Wang QQ, Yin YP, Liang GJ, Jiang N, Yang LG, et al. Prevalence of syphilis infection in different tiers of female sex workers in China: Implications for surveillance and interventions. BMC Infect Dis. 2012;12.

33. Choi SYP, Holroyd E. The influence of power, poverty and agency in the negotiation of condom use for female sex workers in mainland China. Cult Heal Sex. 2007;9(5):489–503.

34. Huang Y, Henderson GE, Pan S, Cohen MS. HIV/AIDS risk among brothel-based female sex workers in China: Assessing the terms, content, and knowledge of sex work. Sex Transm Dis. 2004;31(11):695–700.

35. Tucker JD, Peng H, Wang K, Chang H, Zhang SM, Yang LG, et al. Female sex worker social networks and STI/HIV prevention in South China. PLoS One. 2011;6(9).

36. Hao C, Liu H, Sherman SG, Jiang B, Li X, Xu Y, et al. Typology of older female sex workers and sexual risk for HIV infection in China: a qualitative study. Cult Heal Sex. 2014;16(1):47–60.

37. McLaughlin MM, Chow EPF, Wang C, Yang LG, Yang B, Huang JZ, et al. Sexually Transmitted Infections among Heterosexual Male Clients of Female Sex Workers in China: A Systematic Review and Meta-Analysis. PLoS One. 2013;8(8).

38. White RG. Commentary: What can we make of an association between human immunodeficiency virus prevalence and population mobility? Vol. 32, International Journal of Epidemiology. 2003. p. 753–4.

39. Hesketh T, Li L, Ye X, Wang H, Jiang M, Tomkins A. HIV and syphilis in migrant workers in eastern China. Vol. 82, Sexually Transmitted Infections. 2006. p. 11–4.

40. Coffee M, Lurie MN, Garnett GP. Modelling the impact of migration on the HIV epidemic in South Africa. Aids. 2007;21(3):343–50.

41. Kun S, Shan L, Wei G, Dongmin L. Progress of research on influencing factors of condom use among female sex workers. Chinese J Endem. 2018;39(8):1135–42.

42. Yi H, Mantell JE, Wu R, Lu Z, Zeng J, Wan Y. A profile of HIV risk factors in the context of sex work environments among migrant female sex workers in Beijing, China. Psychol Heal Med. 2010;15(2):172–87.

43. Choi SYP. State control, female prostitution and HIV prevention in China. China Q. 2011;(205):96–114.

44. Tucker J, Ren X, Sapio F. Incarcerated sex workers and HIV prevention in China: Social suffering and social justice countermeasures. Soc Sci Med. 2010;70(1):121–9.

45. Kaufman J. HIV, sex work, and civil society in China. J Infect Dis. 2011/11/09. 2011;204(SUPPL. 5):S1218-22.

46. Wang Y, Li B, Pan J, Sengupta S, Emrick CB, Cohen MS, et al. Factors associated with utilization of a free HIV VCT clinic by female sex workers in Jinan City, Northern China. AIDS Behav. 2011;15(4):702–10.

47. Portes A. Social capital: Its origins and applications in modern sociology. Knowl Soc Cap. 2009;43–68.

48. Perry BL, Pescosolido BA, Borgatti SP, Molina González JL. Egocentric network

analysis: Foundations, methods, and models. Vol. 29, Redes. Revista hispana para el análisis de redes sociales. Cambridge, UK ; New York, NY: Cambridge University Press; 2018. 303 p.

49. Kekwaletswe CT, Jordaan E, Nkosi S, Morojele NK. Social Support and the Mediating Roles of Alcohol Use and Adherence Self-Efficacy on Antiretroviral Therapy (ART) Adherence Among ART Recipients in Gauteng, South Africa. AIDS Behav. 2017;21(7):1846–56.

50. Kapadia F, Siconolfi DE, Barton S, Olivieri B, Lombardo L, Halkitis PN. Social support network characteristics and sexual risk taking among a racially/ethnically diverse sample of young, urban men who have sex with men. AIDS Behav. 2013/04/05. 2013;17(5):1819–28.

51. Hough ES, Magnan MA, Templin T, Gadelrab HF. Social network structure and social support in HIV-positive inner city mothers. J Assoc Nurses AIDS Care. 2006/01/27. 2005;16(4):14–24.

52. Choi KH, Ayala G, Paul J, Boylan R, Gregorich SE. Social network characteristics and HIV risk among African American, Asian/Pacific islander, and Latino men who have sex with men. J Acquir Immune Defic Syndr. 2013/08/13. 2013;64(5):496–501.

53. Qiao S, Li X, Zhang C, Zhou Y, Shen Z, Tang Z. Social Support and Condom Use Among Female Sex Workers in China. Health Care Women Int. 2015;36(7):834–50.

54. Knowlton AR, Hua W, Latkin C. Social support networks and medical service use among HIV-positive injection drug users: Implications to intervention. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2005;17(4):479–92.

55. Veinot TC, Caldwell E, Loveluck J, Arnold MP, Bauermeister J. HIV Testing Behavior and Social Network Characteristics and Functions Among Young Men Who have Sex with Men (YMSM) in Metropolitan Detroit. AIDS Behav. 2016;20(11):2739–61.

56. Cornwell B. Good health and the bridging of structural holes. Soc Networks. 2009;31(1):92–103.

57. Guida JL, Holt CL, Dallal CM, He X, Gold R, Liu H. Social Relationships and Functional Impairment in Aging Cancer Survivors: A Longitudinal Social Network Study. Gerontologist. 2019;

58. Chanda MM, Perez-Brumer AG, Ortblad KF, Mwale M, Chongo S, Kamungoma N, et al. Barriers and Facilitators to HIV Testing among Zambian Female Sex Workers in Three Transit Hubs. AIDS Patient Care STDS. 2017;31(7):290–6.

59. Wang Y, Pan J Bin, Wang XF, Li B, Henderson G, Emrick CB, et al. Reported willingness and associated factors related to utilization of voluntary counseling and testing services by female sex workers in Shandong Province, China. Biomed Environ Sci. 2010;23(6):466–72.

60. Putnam RD. Bowling alone: The collapse and revival of American community. Simon and schuster; 2000.

61. Centola D. The spread of behavior in an online social network experiment. Science (80-). 2010;329(5996):1194–7.

62. Morrow E, Scorgie-Porter L. Bowling Alone: The Collapse and Revival of American

Community. Bowling Alone: The Collapse and Revival of American Community. 2017. 1–84 p.

63. Albarracín D, Kumkale GT, Johnson BT. Influences of social power and normative support on condom use decisions: A research synthesis. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2004;16(6):700–23.

64. Rudolph AE, Linton S, Dyer TP, Latkin C. Individual, network, and neighborhood correlates of exchange sex among female non-injection drug users in Baltimore, MD (2005-2007). AIDS Behav. 2013;17(2):598–611.

65. Yang XY, Yang T. Nativity Homogeneity in Social Networks and Prostitution Patronage Among Male Migrant Laborers. AIDS Behav. 2019;23(5):1339–51.

66. Brooks BA. The Strength of Weak Ties. In: Nurse Leader. Elsevier; 2019. p. 90–2.

67. Granovetter MS. The Strenght of Weak TIes. Jstor. 1973;78(6):1360–80.

68. Liu H. Can Burt's Theory of Structural Holes be Applied to Study Social Support Among Mid-Age Female Sex Workers? A Multi-Site Egocentric Network Study in China. AIDS Behav. 2017/08/23. 2017;21(12):3567–77.

69. Tokar A, Broerse JEW, Blanchard J, Roura M. HIV Testing and Counseling Among Female Sex Workers: A Systematic Literature Review. AIDS Behav. 2018;22(8):2435–57.

70. Hong Y, Fang X, Li X, Liu Y, Li M. Environmental support and HIV prevention behaviors among female sex workers in China. Sex Transm Dis. 2008;35(7):662–7.

71. Wang Y, Li B, Zheng J, Sengupta S, Emrick CB, Cohen MS, et al. Factors related to female sex workers' Willingness to utilize VCT service: A qualitative study in Jinan City, Northern China. AIDS Behav. 2009;13(5):866–72.

72. Barrington C, Latkin C, Sweat MD, Moreno L, Ellen J, Kerrigan D. Talking the talk, walking the walk: Social network norms, communication patterns, and condom use among the male partners of female sex workers in La Romana, Dominican Republic. Soc Sci Med. 2009/04/10. 2009;68(11):2037–44.

73. Lai J, Qin C, Nehl EJ, Jiang J, Huang Y, Liang B, et al. HIV prevalence among female sex workers in Guigang City, Guangxi, China: An 8-year consecutive cross-sectional study. BMC Public Health. 2018;18(1).

74. Hail-Jares K, Chang RCF, Choi S, Zheng H, He N, Huang ZJ. Intimate-partner and client-initiated violence among female street-based sex workers in China: Does a support network help? PLoS One [Internet]. 2015 [cited 2020 Jan 20];10(9):e0139161. Available from: http://www.

75. Chen R, Tao F, Ma Y, Zhong L, Qin X, Hu Z. Associations between social support and condom use among commercial sex workers in China: A cross-sectional study. PLoS One. 2014;9(12):e113794.

76. Gu J, Bai Y, Lau JTF, Hao Y, Cheng Y, Zhou R, et al. Social environmental factors and condom use among female injection drug users who are sex workers in China. AIDS Behav. 2014;18(SUPPL. 2).

77. Liu H. Egocentric network and condom use among mid-age female sex workers in China:

A multilevel modeling analysis. AIDS Patient Care STDS. 2016;30(4):155–65.

78. Fauk NK, Sukmawati AS, Berek PAL, Ernawati, Kristanti E, Wardojo SSI, et al. Barriers to HIV testing among male clients of female sex workers in Indonesia. Int J Equity Health. 2018;17(1):68.

79. Lahuerta M, Torrens M, Sabidó M, Batres A, Casabona J. Sexual risk behaviours and barriers to HIV testing among clients of female sex workers in Guatemala: A qualitative study. Cult Heal Sex. 2013;15(7):759–73.

80. Siu GE, Wight D, Seeley JA. Masculinity, social context and HIV testing: An ethnographic study of men in Busia district, rural eastern Uganda. BMC Public Health. 2014;14(1).

81. Rouhani SA, O'Laughlin KN, Faustin ZM, Tsai AC, Kasozi J, Ware NC. The role of social support on HIV testing and treatment adherence: A qualitative study of HIV-infected refugees in southwestern Uganda. Glob Public Health. 2017;12(8):1051–64.

82. Dandona R, Dandona L, Kumar GA, Gutierrez JP, McPherson S, Bertozzi SM. HIV testing among female sex workers in Andhra Pradesh, India. Aids. 2005;19(17):2033–6.

83. Fonner VA, Kerrigan D, Mnisi Z, Ketende S, Kennedy CE, Baral S. Social cohesion, social participation, and HIV related risk among female sex workers in Swaziland. PLoS One [Internet]. 2014/02/06. 2014;9(1):e87527. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24498125

84. King EJ, Maman S, Bowling JM, Moracco KE, Dudina V. The influence of stigma and discrimination on female sex workers' access to hiv services in St. Petersburg, Russia. AIDS Behav. 2013;17(8):2597–603.

85. Wagner GJ, Hoover M, Green H, Tohme J, Mokhbat J. Social, Relational and Network Determinants of Unprotected Anal Sex and HIV Testing Among Men Who Have Sex with Men in Beirut, Lebanon. Int J Sex Heal. 2015;27(3):264–75.

86. Liu H, Feng T, Liu H, Feng H, Cai Y, Rhodes AG, et al. Egocentric networks of Chinese men who have sex with men: Network components, condom use norms, and safer sex. AIDS Patient Care STDS. 2009;23(10):885–93.

87. Wagner KD, Syvertsen JL, Verdugo SR, Molina JL, Strathdee SA. A mixed methods study of the social support networks of female sex workers and their primary noncommercial male partners in Tijuana, Mexico. J Mix Methods Res [Internet]. 2018;12(4):437–57. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=30245602&site=ehost-live

88. Everett M, Borgatti SP. Ego network betweenness. Soc Networks. 2005;27(1):31–8.

89. Skaathun B, Voisin DR, Cornwell B, Lauderdale DS, Schneider JA. A Longitudinal Examination of Factors Associated with Network Bridging Among YMSM: Implications for HIV Prevention. AIDS Behav [Internet]. 2019 [cited 2020 Jan 21];23(5):1326–38. Available from: https://doi.org/10.1007/s10461-018-2258-3

90. Schneider JA, Lancki N, Schumm P. At the intersection of criminal justice involvement and sexual orientation: Dynamic networks and health among a population-based sample of young Black men who have sex with men. Soc Networks [Internet]. 2017 Oct [cited 2020 Jan 21];51:73–87. Available from:

https://linkinghub.elsevier.com/retrieve/pii/S0378873316302052

91. Triandis HC. Collectivism and Individualism as Cultural Syndromes. Cross-Cultural Res. 1993;27(3–4):155–80.

92. Matsumoto D, Weissman MD, Preston K, Brown BR, Kupperbusch C. Context-specific measurement of individualism-collectivism on the individual level: The individualism-collectivism interpersonal assessment inventory. J Cross Cult Psychol. 1997;28(6):743–67.

93. Liu SS, Morris MW, Talhelm T, Yang Q. Ingroup vigilance in collectivistic cultures. Proc Natl Acad Sci U S A. 2019;116(29):14538–47.

94. Hong Y, Fang X, li X, Liu Y, li M, Tai-Seale T. Self-Perceived Stigma, Depressive Symptoms, and Suicidal Behaviors Among Female Sex Workers in China. J Transcult Nurs. 2010;21(1):29–34.

95. Zang C, Guida J, Sun Y, Liu H. Collectivism culture, HIV stigma and social network support in Anhui, China: A path analytic model. AIDS Patient Care STDS. 2014;28(8):452–8.

96. Liu H, Feng T, Ha T, Liu H, Cai Y, Liu X, et al. Chinese culture, homosexuality stigma, social support, and condom use: A path analytic model. Stigma Res Action. 2011;1(1).

97. Johnson BT, Redding CA, Diclemente RJ, Mustanski BS, Dodge B, Sheeran P, et al. A network-individual-resource model for HIV prevention. AIDS Behav. 2010;14(SUPPL. 2).

98. Valente TW. Social Networks and Health: Models, Methods, and Applications. Social Networks and Health: Models, Methods, and Applications. 2010. 1–296 p.

99. McMillan B, Conner M. Applying an Extended Version of the Theory of Planned Behavior to Illicit Drug Use among Students. J Appl Soc Psychol. 2003;33(8):1662–83.

100. Rhodes T. Risk environments and drug harms: A social science for harm reduction approach. International Journal of Drug Policy. 2009;20(3):193–201.

101. Fonner VA, Kerrigan D, Mnisi Z, Ketende S, Kennedy CE, Baral S. Social cohesion, social participation, and HIV related risk among female sex workers in Swaziland. PLoS One [Internet]. 2014/02/06. 2014;9(1):e87527. Available from: https://www.ncbi.nlm.nih.gov/pubmed/24498125

102. Lippman SA, Donini A, Díaz J, Chinaglia M, Reingold A, Kerrigan D. Social-environmental factors and protective sexual behavior among sex workers: The Encontros intervention in Brazil. Am J Public Health. 2010;100(SUPPL. 1).

103. Liu H, Morisky DE, Lin X, Ma E, Jiang B, Yin Y. Bias in Self-Reported Condom Use: Association Between Over-Reported Condom Use and Syphilis in a Three-Site Study in China. AIDS Behav. 2016;20(6):1343–52.

104. Guida J, Fukunaga A, Liu H. Biomarker validation of self-reported sex among middle-aged female sex workers in China. Ann Epidemiol. 2017;27(3):181-186.e1.

105. Latkin CA, Knowlton AR. Social Network Assessments and Interventions for Health Behavior Change: A Critical Review. Behav Med. 2015;41(3):90–7.

106. Council.P.R.China NH. China Health Statistical Yearbook. Peking Union Medical College

Press. 2019.

107. Liu H, Li J, Ha T, Li J. Assessment of Random Recruitment Assumption in Respondent-Driven Sampling in Egocentric Network Data*. Soc Netw. 2012;01(02):13–21.

108. Heckathorn DD. Extensions of respondent-driven sampling: Analyzing continuous variables and controlling for differential recruitment. Sociol Methodol. 2007;37(1):151–207.

109. Ramadhani HO, Liu H, Nowak RG, Crowell TA, Ndomb T, Gaydos C, et al. Sexual partner characteristics and incident rectal Neisseria gonorrhoeae and Chlamydia trachomatis infections among gay men and other men who have sex with men (MSM): A prospective cohort in Abuja and Lagos, Nigeria. Sex Transm Infect. 2017;93(5):348–55.

110. Volz E, Heckathorn D. Probability based estimation theory for respondent driven sampling. J Off Stat. 2008;24(1):79–97.

111. Watts DJ, Strogatz SH. Collective dynamics of "small-world" networks. In: The Structure and Dynamics of Networks. Princeton University Press; 2011. p. 301–3.

112. Koram N, Liu H, Li J, Li J, Luo J, Nield J. Role of social network dimensions in the transition to injection drug use: Actions speak louder than words. AIDS Behav. 2011/03/25. 2011;15(7):1579–88.

113. Matsumoto D. The Individualism-Collectivism Interpersonal Assessment Inventory (ICIAI): A domain specific measure of individualistic and collectivistic values related to social interaction. Cult Emot Res Lab Dep Psychol San Fr State Univ. 1996;

114. Wu F, He X, Guida J, Xu Y, Liu H. Network stigma towards people living with HIV/AIDS and their caregivers: An egocentric network study. Glob Public Health. 2015/02/03. 2015;10(9):1032–45.

115. Guida J, Hu L, Liu H. The Impact of Occupational Stigma on the Social Networks of Older Female Sex Workers: Results from a Three-Site Egocentric Network Study in China. Vol. 30, AIDS Patient Care and STDs. 2016. p. 1–3.

116. Chow EPF, Muessig KE, Yuan L, Wang Y, Zhang X, Zhao R, et al. Risk behaviours among female sex workers in China: A systematic review and data synthesis. PLoS One. 2015;10(3):e0120595.

117. Global HIV Prevention Coalition. Implementation of the HIV Prevention 2020 Road Map. UNAIDS. 2019.

118. Baral S, Beyrer C, Muessig K, Poteat T, Wirtz AL, Decker MR, et al. Burden of HIV among female sex workers in low-income and middle-income countries: A systematic review and meta-analysis. Lancet Infect Dis. 2012;12(7):538–49.

119. Huang ZJ, Wang W, Martin MC, Nehl EJ, Smith BD, Wong FY. "Bridge population": Sex workers or their clients? - STI prevalence and risk behaviors of clients of female sex workers in China. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2011;23(SUPPL. 1):45–53.

120. Fajans P, Ford K, Wirawan DN. AIDS knowledge and risk behaviors among domestic clients of female sex workers in Bali, Indonesia. Soc Sci Med. 1995;41(3):409–17.

121. Yang H, Li X, Stanton B, Fang X, Zhao R, Dong B, et al. Condom use among female sex

workers in China: Role of gatekeepers. Sex Transm Dis. 2005;32(9):572–80.

122. Pan S, Parish WL, Huang Y. Clients of female sex workers: A population-based survey of China. Vol. 204, Journal of Infectious Diseases. 2011.

123. Mayer KH, Allan-Blitz LT. Similar, but different: drivers of the disproportionate HIV and sexually transmitted infection burden of key populations. J Int AIDS Soc. 2019;22(S6).

124. Yang X, Xia G, Li X, Latkin C, Celentano D. Social influence and individual risk factors of HIV unsafe sex among female entertainment workers in China. AIDS Educ Prev. 2010;22(1):69–86.

125. Wasserman S, Faust K. Social network analysis: Methods and applications. Vol. 8. Cambridge university press; 1994.

126. Helleringer S, Kohler HP. Sexual network structure and the spread of HIV in Africa: Evidence from Likoma Island, Malawi. Aids. 2007;21(17):2323–32.

127. Rienties B, Héliot YF, Jindal-Snape D. Understanding social learning relations of international students in a large classroom using social network analysis. High Educ. 2013;

128. Perry BL, Pescosolido BA, Borgatti SP. Egocentric network analysis: Foundations, methods, and models. Vol. 44. Cambridge University Press; 2018.

129. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS med. 2009;6(7):e1000097.

130. Burt RS, Meltzer DO, Seid M, Borgert A, Chung JW, Colletti RB, et al. What's in a name generator? Choosing the right name generators for social network surveys in healthcare quality and safety research. BMJ Qual Saf. 2012;21(12):992–1000.

131. Annadurai K, Bagavandas M. A study of Female Sex worker's sub-network on STI treatment seeking behavior in Chennai City: A Social Network Approach. INDIAN J COMMUNITY Heal. 2017;29(3):239–44.

132. Felsher M, Koku E. Explaining HIV Risk Multiplexity: A Social Network Analysis. AIDS Behav. 2018/04/24. 2018;22(11):3500–7.

133. Woodhouse DE, Rothenberg RB, Potterat JJ, Darrow WW, Muth SQ, Klovdahl AS, et al. Mapping a social network of heterosexuals at high risk for HIV infection. AIDS. 1994 Sep;8(9):1331–6.

134. Klovdahl AS, Potterat JJ, Woodhouse DE, Muth JB, Muth SQ, Darrow WW. Social networks and infectious disease: The Colorado Springs study. Soc Sci Med. 1994/01/01. 1994;38(1):79–88.

135. Remple VP, Patrick DM, Johnston C, Tyndall MW, Jolly AM. Clients of indoor commercial sex workers: heterogeneity in patronage patterns and implications for HIV and STI propagation through sexual networks. Sex Transm Dis. 2007 Oct;34(10):754–60.

136. Rothenberg RB, Potterat JJ, Woodhouse DE, Muth SQ, Darrow WW, Klovdahl AS. Social network dynamics and HIV transmission. Aids. 1998/09/04. 1998;12(12):1529–36.

137. Yu YJ, McCarty C, Wang B. Network and Individual Factors Associated with Drug Use among Female Sex Workers (FSWs) in Southern China: A Mixed-Method Approach.

Subst Use Misuse. 2018 Sep;53(11):1763–70.

138. Dong X, Sun M, Wang J, Yang Z, Hu B. Understanding the Hierarchical Relationships in Female Sex Workers' Social Networks Based on Knowledge, Attitude, and Practice. Int J Environ Res Public Health. 2019 Oct;16(20).

139. Liu H, Zhao M, Wang Y, Feldman MW, Xiao Q. The sexual networks of female sex workers and potential HIV transmission risk: an entertainment venue-based study in Shaanxi, China. Int J STD AIDS [Internet]. 2020 Mar 19;956462419886780. Available from: http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=32192372&site=ehost-live

140. Deuba K, Anderson S, Ekstrom AM, Pandey SR, Shrestha R, Karki DK, et al. Micro-level social and structural factors act synergistically to increase HIV risk among Nepalese female sex workers. Int J Infect Dis. 2016 Aug;49:100–6.

141. Kossinets G. Effects of missing data in social networks. Soc Networks. 2006;28(3):247–68.

142. Young LE, Fujimoto K, Schneider JA. Facebook group affiliation ties, group topics, and HIV behavioral characteristics among young Black men who have sex with men: Potential for public health intervention. SSM - Popul Heal. 2019;9.

143. Rocha LEC, Liljeros F, Holme P. Information dynamics shape the sexual networks of Internet-mediated prostitution. Proc Natl Acad Sci U S A. 2010;107(13):5706–11.

144. Hsieh CS, Kovářík J, Logan T. How central are clients in sexual networks created by commercial sex? Sci Rep. 2014;4.

145. Cao B, Liu C, Durvasula M, Tang W, Pan S, Saffer AJ, et al. Social media engagement and HIV testing among men who have sex with men in China: A nationwide cross-sectional survey. J Med Internet Res. 2017;19(7).

146. Gile KJ, Handcock MS. Analysis of networks with missing data with application to the National Longitudinal Study of Adolescent Health. J R Stat Soc Ser C Appl Stat. 2017;66(3):501–19.

147. Wang C, Butts CT, Hipp JR, Jose R, Lakon CM. Multiple imputation for missing edge data: A predictive evaluation method with application to Add Health. Soc Networks. 2016;45:89–98.

148. Chéret A, Bacchus-Souffan C, Avettand-Fenoël V, Mélard A, Nembot G, Blanc C, et al. Combined ART started during acute HIV infection protects central memory CD41 T cells and can induce remission. J Antimicrob Chemother. 2015;70(7):2108–20.

149. Lundgren JD, Babiker AG, Gordin F, Emery S, Grund B, Sharma S, et al. Initiation of antiretroviral therapy in early asymptomatic HIV infection. N Engl J Med. 2015;373(9):795–807.

150. Zolopa AR, Andersen J, Komarow L, Sanne I, Sanchez A, Hogg E, et al. Early antiretroviral therapy reduces AIDS progression/death in individuals with acute opportunistic infections: A multicenter randomized strategy trial. PLoS One. 2009;4(5):e5575 %! Early antiretroviral therapy reduces AIDS.

151. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, Kumarasamy N, et al.

Prevention of HIV-1 infection with early antiretroviral therapy. N Engl J Med. 2011;365(6):493–505.

152. Rodger AJ, Cambiano V, Bruun T, Vernazza P, Collins S, Van Lunzen J, et al. Sexual activity without condoms and risk of HIV transmission in serodifferent couples when the HIV-positive partner is using suppressive antiretroviral therapy. JAMA - J Am Med Assoc. 2016;316(2):171–81.

153. Xu J, Brown K, Ding G, Wang H, Zhang G, Reilly K, et al. Factors associated with HIV testing history and HIV-test result follow-up among female sex workers in two cities in Yunnan, China. Vol. 38, Sexually Transmitted Diseases. 2011. p. 89–95.

154. Liao M, Bi Z, Liu X, Kang D, Fu J, Song Q, et al. Condom use, intervention service utilization and HIV knowledge among female sex workers in China: Results of three consecutive cross-sectional surveys in Shandong Province with historically low HIV prevalence. Int J STD AIDS. 2012;23(3).

155. Hong Y, Zhang C, Li X, Fang X, Lin X, Zhou Y, et al. HIV testing behaviors among female sex workers in southwest China. AIDS Behav. 2012;16(1):44–52.

156. Shannon K, Strathdee SA, Goldenberg SM, Duff P, Mwangi P, Rusakova M, et al. Global epidemiology of HIV among female sex workers: Influence of structural determinants. Vol. 385, The Lancet. 2015. p. 55–71.

157. Chiao C, Morisky DE, Ksobiech K, Malow RM. Promoting HIV testing and condom use among filipina commercial sex workers: Findings from a quasi-experimental intervention study. AIDS Behav. 2009;13(5):892–901.

158. Shen Z, Zhang C, Li X, Su S, Cui Y, Zhou Y, et al. HIV-related behavioral risk factors among older female sex workers in Guangxi, China. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2014;26(11):1407–10.

159. King EJ, Maman S, Dudina VI, Moracco KE, Bowling JM. Motivators and barriers to HIV testing among street-based female sex workers in St. Petersburg, Russia. Glob Public Health. 2017;12(7):876–91.

160. Lelutiu-Weinberger C, Wilton L, Koblin BA, Hoover DR, Hirshfield S, Chiasson MA, et al. The Role of Social Support in HIV Testing and PrEP Awareness among Young Black Men and Transgender Women Who Have Sex with Men or Transgender Women. J Urban Heal. 2020;1–13.

161. Painter TM, Song EY, Mullins MM, Mann-Jackson L, Alonzo J, Reboussin BA, et al. Social Support and Other Factors Associated with HIV Testing by Hispanic/Latino Gay, Bisexual, and Other Men Who Have Sex with Men in the U.S. South. AIDS Behav. 2019;23:251–65.

162. Cao B, Saffer AJ, Yang C, Chen H, Peng K, Pan SW, et al. MSM Behavior Disclosure Networks and HIV Testing: An Egocentric Network Analysis Among MSM in China. AIDS Behav. 2019;23(5):1368–74.

163. Coleman JS. Social capital in the creation of human capital. Knowl Soc Cap. 2009;94:17–42.

164. Lazega E, Burt RS. Structural Holes: The Social Structure of Competition. Vol. 36, Revue Française de Sociologie. Cambridge, Mass.: Harvard University Press; 1995. 779 p.

165. Delva W, Leventhal GE, Helleringer S. Connecting the dots: Network data and models in HIV epidemiology. Aids. 2016/06/18. 2016;30(13):2009–20.

166. Norbeck JS. The Norbeck Social Support Questionnaire. Birth Defects Orig Artic Ser. 1984;20(5):45–57.

167. Latkin C, Mandell W, Oziemkowska M, Celentano D, Vlahov D, Ensminger M, et al. Using social network analysis to study patterns of drug use among urban drug users at high risk for HIV/AIDS. Drug Alcohol Depend. 1995/04/01. 1995;38(1):1–9.

168. Lee SS, Tam DKP, Ho RLM, Wong KH. Social network methodology for studying HIV epidemiology in men having sex with men. J Infect Public Health. 2009;2(4):177–83.

169. Snijders TAB. Transitivity and Triads. Structure. 2012;

170. Borgatti SP, Everett MG, Freeman LC. Ucinet. Encycl Soc Netw Anal Min. 2014;2261–7.

171. Pemberton JR. Retention of mercurial preservatives in desiccated biological products. J Clin Microbiol. 1975;2(6):549–51.

172. Gallo MF, Steiner MJ, Hobbs MM, Warner L, Jamieson DJ, MacAluso M. Biological markers of sexual activity: Tools for improving measurement in HIV/sexually transmitted infection prevention research. Sex Transm Dis. 2013;40(6):447–52.

173. Ell K. Social networks, social support, and health status: A review. Soc Serv Rev. 1984;58(1):133–49.

174. Leserman J, Petitto JM, Golden RN, Gaynes BN, Gu H, Perkins DO, et al. Impact of stressful life events, depression, social support, coping, and cortisol on progression to AIDS. Am J Psychiatry. 2000;157(8):1221–8.

175. Heaney CA, Israel BA. Social networks and social support. Heal Behav Heal Educ Theory, Res Pract. 2008;4:189–210.

176. O'Malley AJ, Arbesman S, Steiger DM, Fowler JH, Christakis NA. Egocentric social network structure, health, and pro-social behaviors in a national panel study of Americans. PLoS One [Internet]. 2012 [cited 2020 Jan 20];7(5):36250. Available from: www.plosone.org

177. Kerrigan D, Ellen JM, Moreno L, Rosario S, Katz J, Celentano DD, et al. Environmental-structural factors significantly associated with consistent condom use among female sex workers in the Dominican Republic. Aids. 2003;17(3):415–23.

178. Li Q, Li X, Stanton B, Fang X, Zhao R. A multilevel analysis of gatekeeper characteristics and consistent condom use among establishment-based female sex workers in Guangxi, China. Sex Transm Dis. 2010;37(11):700–5.

179. Wanyenze RK, Musinguzi G, Kiguli J, Nuwaha F, Mujisha G, Musinguzi J, et al. "when they know that you are a sex worker, you will be the last person to be treated": Perceptions and experiences of female sex workers in accessing HIV services in Uganda. BMC Int Health Hum Rights. 2017;17(1).

180. Oyserman D, Coon HM, Kemmelmeier M. Rethinking individualism and collectivism: Evaluation of theoretical assumptions and meta-analyses. Psychol Bull. 2002;128(1):3–52.

181. Allik J, Realo A. Individualism-collectivism and social capital. J Cross Cult Psychol. 2004;35(1):29–49.

182. Goodwin R, Hernandez Plaza S. Perceived and received social support in two cultures: Collectivism and support among British and Spanish students. J Soc Pers Relat [Internet]. 2000;17(2):282–91. Available from: http://journals.sagepub.com/doi/abs/10.1177/0265407500172007

183. Mantsios A, Kerrigan D, Mbwambo J, Likindikoki S, Shembilu C. Economic Strengthening Approaches with Female Sex Workers. In: Structural Interventions for HIV Prevention. Oxford University Press; 2018. p. 191–220.

184. Realo A, Allik J, Greenfield B. Radius of trust: Social capital in relation to familism and institutional collectivism. J Cross Cult Psychol. 2008;39(4):447–62.

185. Talhelm T, Zhang X, Oishi S, Shimin C, Duan D, Lan X, et al. Large-scale psychological differences within China explained by rice versus wheat agriculture. Science (80-). 2014;344(6184):603–8.

186. Huang Y, Pan S. Government crackdown of sex work in China: Responses from female sex workers and implications for their health. Glob Public Health. 2014;9(9):1067–79.

187. Simbayi LC, Kalichman S, Strebel A, Cloete A, Henda N, Mqeketo A. Internalized stigma, discrimination, and depression among men and women living with HIV/AIDS in Cape Town, South Africa. Soc Sci Med. 2007;64(9):1823–31.

188. Smith R, Rossetto K, Peterson BL. A meta-analysis of disclosure of one's HIV-positive status, stigma and social support. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2008;20(10):1266–75.

189. Davison KP, Pennebaker JW, Dickerson SS. Who talks? The social psychology of illness support groups. Am Psychol. 2000;55(2):205–17.

190. Hong Y, Zhang C, Li X, Zhou Y, Guo W. Female sex workers and their gatekeepers in china: Implications for HIV/STI prevention. Qual Health Res. 2014;24(10):1431–9.

191. He X, Feng X, Liu P, Lyu Y, Lu H, Ma Y, et al. An innovative vending machine-based HIV testing and intervention service in China: anonymous urine collection kits distributed at universities. AIDS Care - Psychol Socio-Medical Asp AIDS/HIV. 2019;31(10):1319–22.

192. Mitchell KR, Mercer CH, Prah P, Clifton S, Tanton C, Wellings K, et al. Why Do Men Report More Opposite-Sex Sexual Partners Than Women? Analysis of the Gender Discrepancy in a British National Probability Survey. J Sex Res. 2019;56(1):1–8.

193. Berkman LF, Kawachi I, Glymour MM. Social epidemiology. Oxford University Press; 2014.